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The Technograph

VOL. XXX NOVEMBER, 1915 NO. 1

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C. R. RICHARDS

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The Technograph

VOL. XXX NOVEMBER, 1915 No. 1

ORGANIZATION IN THE FOUNDRY OF THE UNIVERSITY OF ILLINOIS SHOP LABORATORIES

BY R. E. KENNEDY AND J. H. HOGUE, URBANA, ILL.

Presented at annual meeting of American Foundrymen's Association, Sept. 28 to Oct. 1.

During the last few years there has been much discussion among the employers of technical graduates and those men who are at the head of the administration of the technical courses in the colleges and universities, as to the value of the training in shop practice given to the undergraduate student.

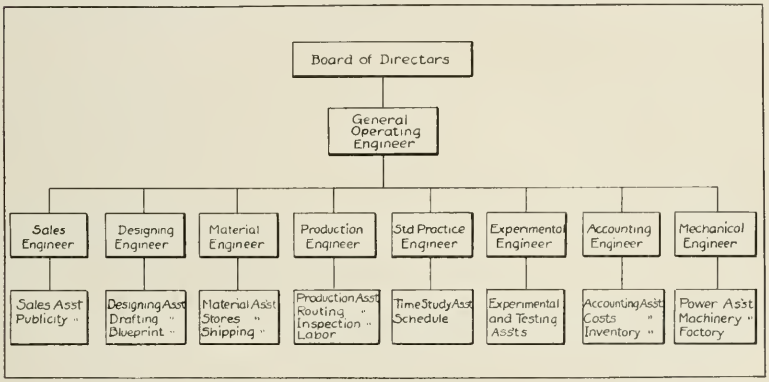

Fig. 1—Outline of the Operating Organization of the Shop Laboratories

The Specialization of the Executive Work is as Necessary in Any Manufacturing Plant as the Specialization of the Duties of the Workman

The purpose of these courses, when first started almost 40 years ago, was to give the college course an air of practicalness and afford the student some training in the elementary principles of shop work. Very few of the students entering the technical schools then had any acquaintance with shop principles and methods of manufacture, and it was necessary first to instill in their minds a knowledge of the elementary shop practices.

Because of the recent advance in trade and manual training teaching in the secondary schools, and the changing demand of the employers of technical graduates, the question as to the advisability of changing, or entirely abandoning the work has

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arisen, and it has become a vital problem to the schools concerned.

The question was aptly stated by Dr. W. F. M. Goss, past president of the American Society of Mechanical Engineers, when he said, "The time has come when the shop laboratory should cease to be content with a grade of work possible in a secondary school; its work should possess a quality and character which is only possible in the environment of the technical school. This implies that the work of the shop laboratories must be interrelated with that of other technical courses, that such laboratories must cease to use equipment which was purchased one or two decades ago, and that they must cease to be satisfied with methods of administration which, in actual shops, have already passed out of existence. If the shops are to mean anything worth while, they must not only respond to the great and significant changes which have been going on outside, but they must have their part in leading such changes. Their work must not stop with routine; it must proceed to the development of research that new principles may be established."

With this problem before them, those in charge of the shop work at the University of Illinois set about reorganizing the work and putting it on a basis where the student would derive the greatest benefit. Thus, not merely to develop skill in hand manipulation, but to develop those qualities needed in the executive rather than those needed by the molder, was the problem to be solved.

To do this, the nature of the work had to be changed from mere teaching of manual training to instructional work showing the principles of modern shop organization.

Reorganization on a Commercial Basis

As the main object of the whole course in shop laboratory work is to teach the engineering students the principles of shop organization, the foundry and other departments of the shop laboratories were reorganized on a commercial basis. A number of standard products were adopted for regular manufacture, among which was a two-cylinder, eight horspower gasoline engine. This engine was the first product developed and standardized.

Orders are issued from the director's office for the erecting of a given number of engines and each department receives its individual order for the parts which it must manufacture.

The method of instruction pursued in the departments of the shop laboratories necessary to carry out this plan can be explained

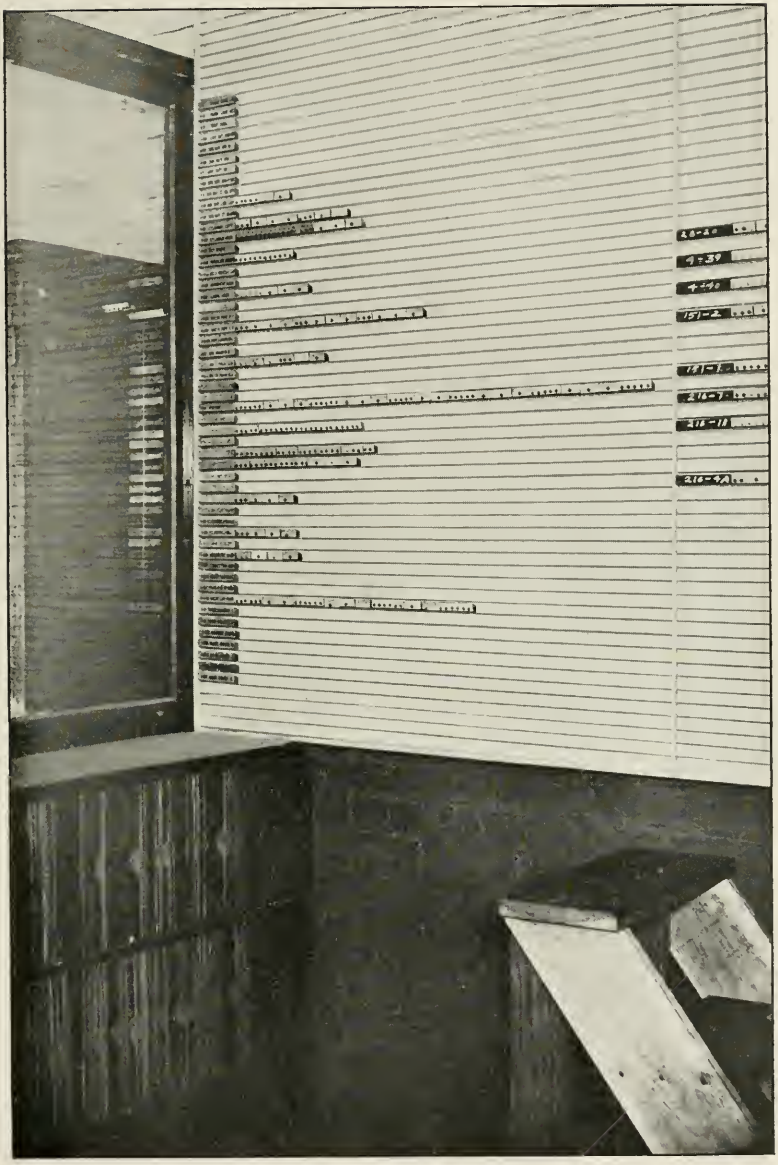

Fig. 2—Work Schedule Board

The Staff Assistant's Office Should be a Place Where is Gathered All the Information Needed For the Planning of Work and Scheduling Its Progress Through the Shop

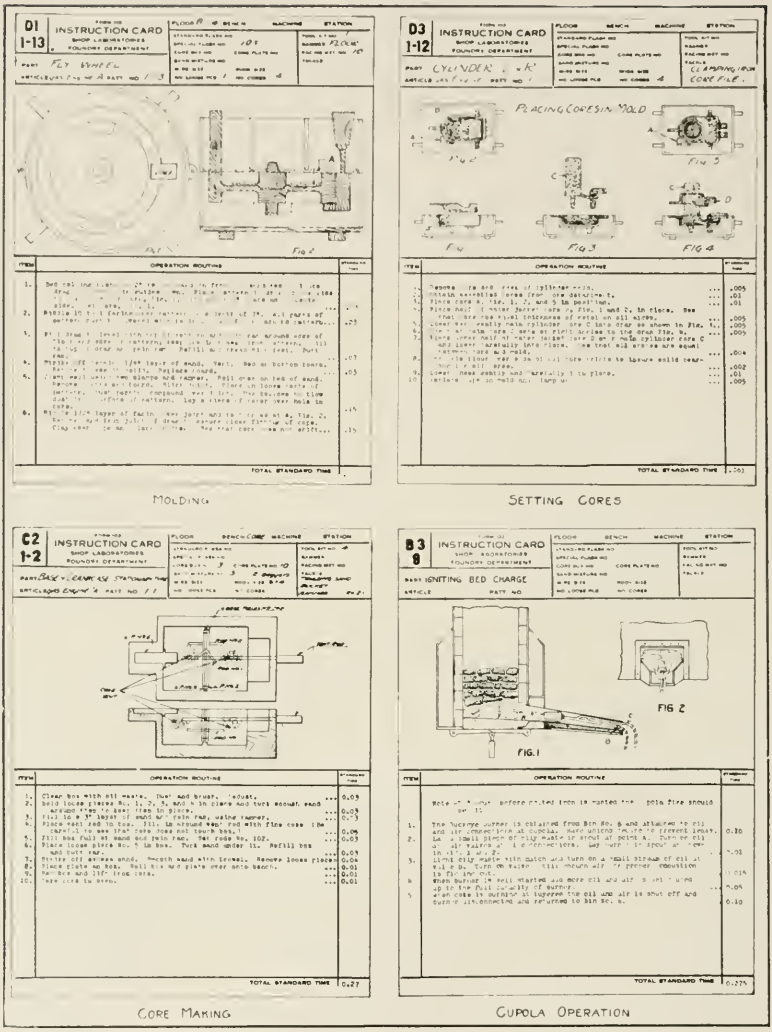

Fig. 3—The Instruction Cards Show How the Work is to Be Performed

by describing the work as followed in the foundry, with a description of the foundry mechanical equipment. All departments, machine, pattern, forge and foundry, are working on the same general plan, although each has its own distinct problems of production, mechanical efficiency and organization.

Preliminary Instructions

The preliminary work of instruction in foundry work is covered by a series of demonstrations and lectures on the essential

FORM 7
UNIVERSITY OF ILLINOIS
SHOP LABORATORIES

RECORD OF TIME STUDY

DEPT._____

OPERATION Core Making
ARTICLE Piston Pattern 1 - 24
INSTRUCTION CARD NO. C 1. 1 - 24 OPER NO 1
OPERATOR'S NAME Sundell, H. A. NO. 24 SEC A
DATE 9/5 1914 TIME STUDY NO. 2

ITEM	DETAILS OF OPERATION	TIME ACTUAL	TIME LOST	TIME PROPOSED	EXPLANATION OF OPERATING TIME LOSSES
1	Placing plate on bench	.03	.02	.01	Could not locate right plate at once
2	Cleaning box	.04	.03	.01	Had been using sand too wet.
3	Place box in position. Assemble	.01		.01	
4	Ram first layer of sand. Set rods.	.05	.04	.01	Rods cut too long. Had to exchange
5	Set 2 loose pieces of box	.01		.01	
6	Fill box and ram. Strike off.	.04		.04	
7	Remove loose pieces. Fill with molding sand	.02	.02		Use of iron dryers would eliminate this item
8	Clamp box. Roll box over on plate	.02	.01	.01	Clamps loose
9	Rap box, and lift	.01		.01	
10	Patching torn corner	.04	.04	.00	Box needs repairing. Send to pattern shop.
11	Blackening	.05	.02	.03	Core maker used a very small brush
12	Carrying to oven	.07	.05	.02	Had to wait for helper
	TOTALS	.39	.23	.16	

INVESTIGATED BY _____ WORK SCHEDULE ENGINEER
STUDY MADE BY: Pope, G. H. WORK SCHEDULE ASSISTANT

Fig. 4—Record of Time Study

A Time Study of a Simple Operation Often Brings to Light Many Things to be Corrected in the Shop Practice. A Well-made Study and Careful Analysis of the Result is One of the Most Beneficial Features Developed by Scientific Management Theories

features of bench and floor molding, coremaking and cupola practice. Immediately after a demonstration of one feature of the work has been made, the students are given some time in which to do the actual work and thus fix the method firmly in their minds.

It has proven to be a fact that the more time spent in

Fig. 5—A Tool Room from which the Workmen can Obtain the Right Tool when Needed is a Paying Investment for any Plant

demonstration, while reducing the actual working time of the student, has resulted in an increase in the production of castings.

In addition to the reading of notes on foundry practice, the students subscribe to one of the leading foundry magazines and study the articles and advertisements. This gives them an insight into the methods used in the most modern shops and makes them familiar with the problems foundrymen are encountering in their work.

Fig. 6—Small Iron, Brass and Aluminum Castings Made by Students During Their First Week's Shop Work

Organization of Shop Forces

These demonstrations and practice periods so cover the work that when they have been completed, the students can be organized into shop forces, and with the proper supervision carry on the work of a producing foundry.

With this organization, the students are divided into two general groups:

1.—Staff assistants or executives.
2.—Producing force.

The staff assistants are six in number:

A.—Production.
B.—Materials.
C.—Mechanical.
D.—Standard practice.
E.—Accounting.
F.—Experimental.

The producing force is divided into the usual groups of

A.—Molders.
B.—Coremakers.
C.—Cupola operators.
D.—Cleaning force.

Fig. 7—Wood Milling Machine Column Casting, Showing the Variation of Work in the Shop Laboratories

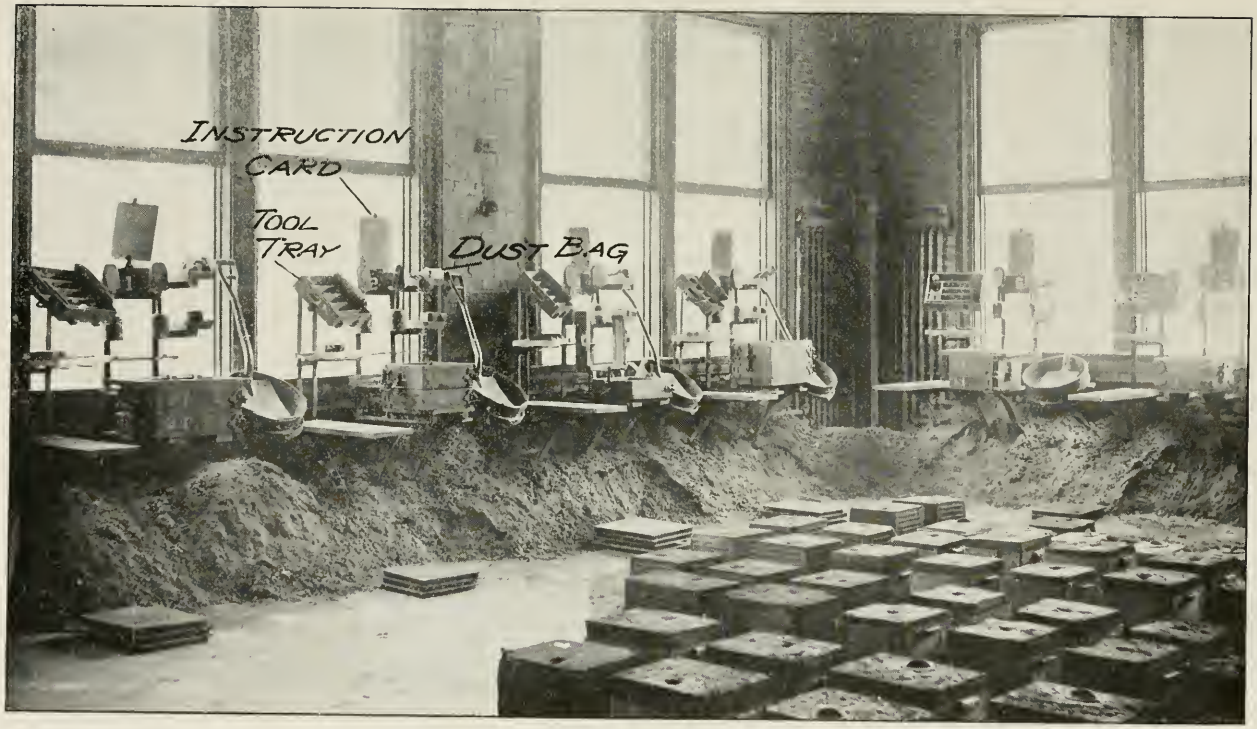

Fig. 8—Much Can Be Done by Molders to so Arrange Their Tools that a Minimum Amount of Time Need Be Spent in Reaching and Replacing Them

The general plan and relation of the functions performed by the staff assistants can be noted in the chart, Fig. 1. To show the work accomplished, the duties of each assistant will be considered in detail.

Production Assistant

The production assistant has charge of shop production, including the working forces and shop equipment. He is responsible for shop output.

As the orders for castings are received, he enters these on his production sheet and announces the schedule for producing these castings. He issues the necessary work orders in their proper order; that is, he first orders the preparing of the material for cores, if cores are to be used, then when this is ready, he issues the orders for making the cores. When the cores are on the stock shelves, the work order to the molder is issued. A work schedule board, Fig. 2, has been placed in the office of the production assistant on which is kept a record of the progress of the work. The work posted on this board is that which should be turned out in one week.

All foundry operations on regular products are standardized and definite instructions are issued in the form of instruction cards, Fig. 3, for the making of each core, core wire, mold, the mixing of core sand and cupola work. These cards contain all the necessary information relative to the production of that piece of work. In the case of a mold, it has the size of flask to be used, the tools needed; the cores used, the place where it is to be worked, an operation routine, and a standard time, which is the time in which the piece should be made if no waste effort occurs. This work of making instruction cards is performed by students, in the manner described later under the heading of *Standard Practice Assistant.*

With this detailed information, the production assistant knows in what order the work should be made and how long it should take. The progress board, when filled out, then is before the assistant as a picture of the way his work is being performed. For each pattern to be used there is placed in the grooves of the board a block on which the pattern number is stamped. Other blocks which indicate the different core and molding operations are placed in the same groove. As the cores are made, this information is sent to the production office and colored tacks are placed in the blocks which indicate the state of work on that particular operation.

With the information of this board before him, the production

assistant can intelligently issue work orders for the making of molds and cores.

He then gives to the materials and mechanical assistants the information as to when and where these cores or molds are to be made and they oversee the preparation so that when the molder or coremaker receives his work order card, he proceeds to the assigned place and finds everything in readiness for the production of the cores or molds, so that he can devote his whole energy to the actual work of coremaking or molding.

As the castings are poured, sent to the cleaning room and then delivered, this information is recorded on the board so that the production assistant can at all times tell the stage of progress of each casting.

This information is brought to the production office by the inspector who keeps track of the cores and molds made and of the good and bad castings poured, cleaned and delivered.

The production assistant also has charge of the operation of the cupola and cleaning of castings, shifting his forces around to suit the needs of the work to be done.

The standardization of such work as mixing core sands and cupola preparations, has proven to be an important factor of success in this work of getting good product from comparatively inexperienced workmen. This same principle of standardization of materials could be employed to great advantage by many foundries which are at present doing the work by the old *hit-or-miss method.*

The workmen, having finished their task, stamp-out on their work order cards and are given another work order, and when they proceed to this work they should find their materials and tools waiting for them.

This method of work forcibly impresses on the student the benefits to be derived from a well-defined plan of knowing how the work is to be done, where it is to be made and when, showing the difference between planning the work in advance and attacking the same without consideration as to methods to be used.

The production assistant, during the time he is holding that position, makes notes of all conditions of shop operation or methods coming under his supervision, which may be changed or eliminated, thereby increasing the efficiency of the shop or bettering the quality of the work. From these notes, he writes a report on conditions and gives his recommendations for improvements.

These reports are discussed and it is considered that the train-

ing derived from the making and discussion of them is one of the most beneficial results of the work in the shop laboratories.

The Material Assistant performs the duties as outlined on the chart, Fig. 1. These duties, in detail, include the keeping of inventory records of materials, which outline the maximum and minimum quantities of materials to be kept on hand for use in the foundry. By the use of the record sheet, the assistant, at

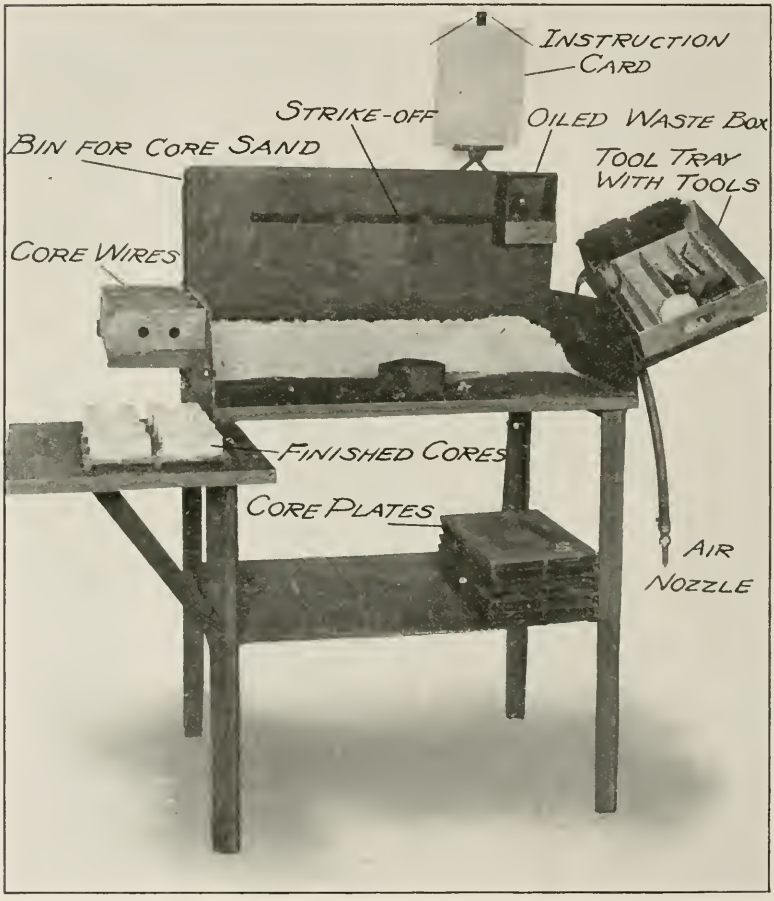

Fig. 9—This Core Bench Arrangement Allows the Coremakers to Turn Out a Large Amount of Work in the Given Space of Time

any time, has a knowledge of the amount of stock on hand, and when this stock is reduced to the minimum quantity, he orders a new supply.

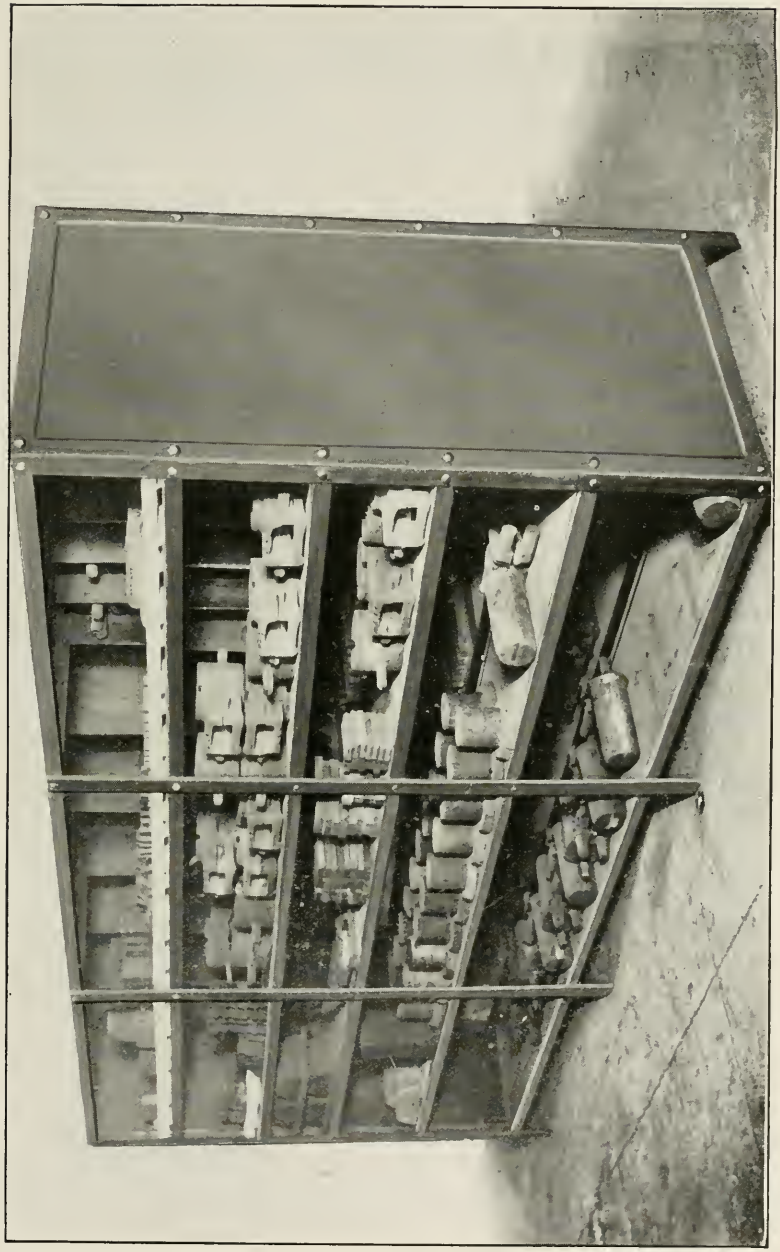

Fig. 10—Core Rack Where the Sets of Cores Are Assembled for the Molders

In ordering he obtains his information as to specifications from the record sheet on which is outlined the place of purchase, analysis or quality, etc.

From the production assistant the materials assistant receives a record of the molds and cores to be made, where they are to be made and when. With this information in hand, it is his duty to see that the molders have all their supplies brought to them, such as cores, graphite, parting compound, nails, etc. He has charge of the mixing of the core sands, cutting of core wires and rods and these he supplies to the coremakers when needed. The instruction cards indicate the kind of core sand needed for each core, and these sands are mixed according to the standard prepared, eliminating the usual guessing as to the amounts of sand, binder and water.

The materials assistant's work puts before the student the importance of knowing the amount of stock on hand, the danger of having materials out of stock, the loss in money to the plant when keeping in stock such large supplies of certain materials because the information as to the amount used in a given period of time is not known.

Mechanical Assistant

The duties of the mechanical assistant consist of the maintenance, in an efficient condition, of all shop tools, machinery and equipment. He has charge of the tool room and its attendant, overseeing the care of the tools kept in this tool room.

He has on record a list of all tools, with the condition in which each tool must be kept to be efficient. This record is called the tool standard and tells when to repair or to discard and replace tools.

It is his duty to oversee the oiling of machinery, repairing broken parts, or recommending the purchase of new equipment. The flask upkeep comes under his supervision and he sees that the flasks and boards are repaired or replaced.

Similar to the materials assistant, the mechanical assistant receives the notice of molds and cores to be made and he prepares the tools and mechanical equipment needed. It is his duty to keep the molders supplied with the right flasks, boards and tools. The coremaker is furnished with the plates needed and necessary tools for the job to be worked.

For the mechanical assistant to know what tools are needed, he must consult the instruction card, on which is recorded all tools, size and kind of flask, plates, or machines needed for the work.

By the co-operation of these three assistants, the work is all planned in advance, eliminating the trouble so often encountered,

when, without planning, a job is started, and then an endless succession of delays are met with and consequent loss of several men's time while waiting for flasks to be brought in, cores to be hunted, tools needed but not to be found, and many more difficulties of the same kind.

This brings to the students' attention the value of planning and preparation in a real, practical demonstration. They see, when they do not perform their part, the consequent loss of time of the other men and the result is more thoroughly impressed on their minds than by any other method.

Standard Practice Assistant

The work of the standard practice assistant, as the title indicates, involves the work of standardizing the shop practices, the method of operation routines and the materials and tools used.

To obtain standards on core sands, facing mixtures and cupola relining mixtures, the students make a study of the qualities of different mixtures, comparing their qualities with each other. The proportions of binder and sand, the amounts of water, the routine of mixing and time of baking are recorded.

In this manner the best core sand mixtures for the various types of cores are found. This information is then recorded on an instruction card and when this mixture is needed the card is used by the materials assistant in preparing this sand for the coremakers.

The standard operation routines and times set on the instruction cards of the types shown in Fig. 3, are obtained by making a detailed time and motion study analysis of different men working on the same piece of work. Care is taken to study the job to discover the best operation routine and the time needed to perform the necessary routine items, while the necessary tools and materials are listed.

The studies being completed, any helpful sketch is placed on the card, the operation routine written and the blue prints are made from the tracing. The prints are pasted on heavy cards and filed away in the staff assistant's office to be issued as needed by the workmen.

This is the treatment for all standard work. For miscellaneous work, a temporary instruction card is written, giving the estimated time, and other information required, such as position of gates, venting, setting of cores, etc.

Therefore, a finished instruction card not only tells the workman how to do a piece of work, but it gives the assistants the information necessary to prepare all tools and materials and it

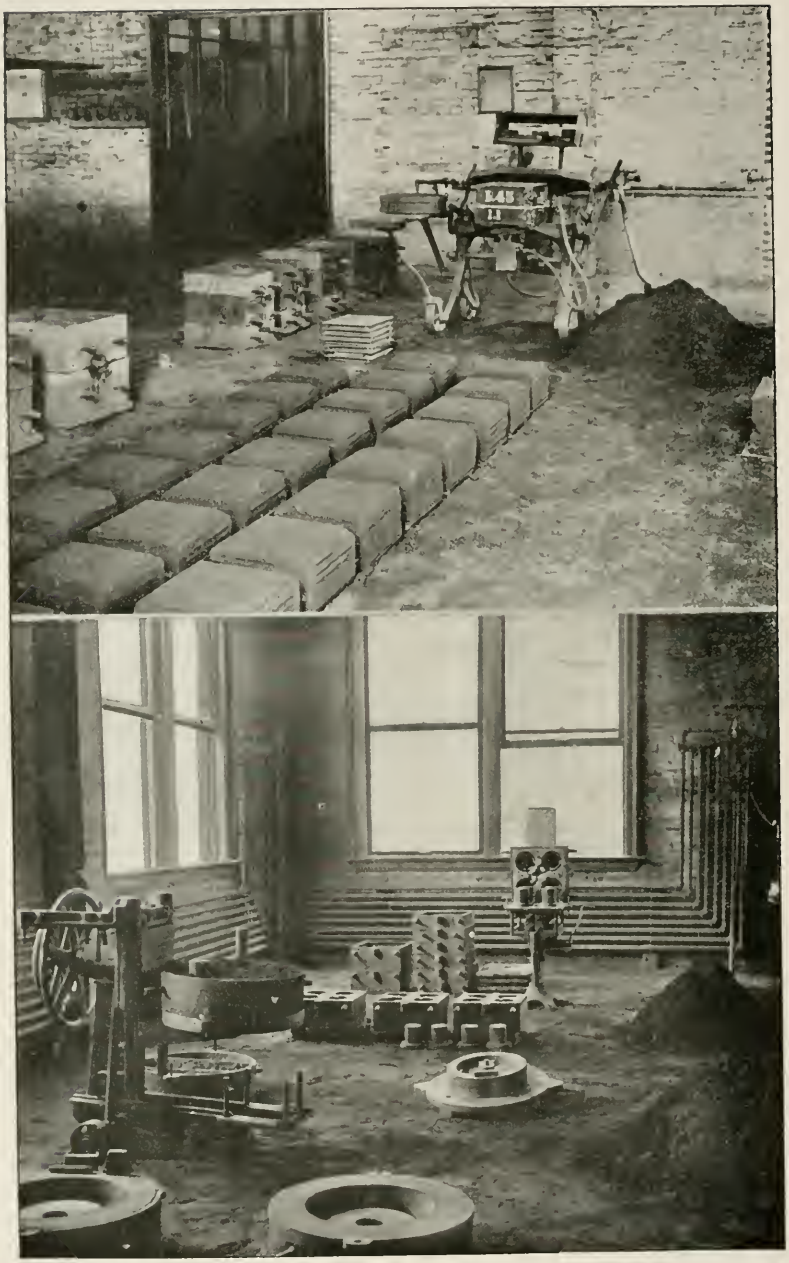

Fig. 11—The Advantages to Be Gained by the Use of the Different Types of Molding Machines Are Taught to the Engineering Students

tells the production assistant how long a given piece of work should take and the order of operation routine.

This work of investigation and time study has proven to be of more value to the students than any other work they perform, as they find that because certain work has always been performed in a certain way in the past is no reason why it should continue to be made that way. The student is always keeping before himself the idea that probably there is a better way of doing the work and it is up to him to make the most thorough study possible to determine the most efficient way. This is training the student to think and analyze conditions for himself.

Experimental Assistants

Due to the nature of manufacturing work there are always new mechanical problems to be investigated and solved. These are slowly solved in ordinary plants by men whose time is supposed to be spent in the regular work of production. The best equipped and most modern concerns have specially trained men in a separate department whose sole duty it is to investigate and test new methods, machines and materials.

The foundry has an unlimited number of such problems and the experimental assistants are given lectures on some of these possibilities, and are then set to work on particular problems relating to this shop. Experiments and tests are made by the students on such subjects as metal mixtures for brass and iron castings, cupola refractories, core sand binders and sands, and on labor saving machines. By carefully analyzing the results of the tests and recording the data obtained, much benefit is gained in the performance of this work.

The work of the accounting assistant includes the care of the inventory records, recording the labor and materials cost on the different orders, and assigning overhead charges to these orders.

He obtains the labor cost from the work order cards, and the materials cost from the information records of the materials assistant.

All the staff assistants make a report on the conditions that come under their observation, which they think can be bettered and their methods for the accomplishment of these changes are set forth in this report.

While the introduction of shop management principles is the main object of the work, the use of a well planned layout of shop equipment has been emphasized and many novel features have been worked out, which could be installed with profit by many shops.

A need was felt for a well-equipped tool room in which to store the small tools, commonly used in a foundry. One of the

greatest sources of lost time in foundry operation is caused by the workman not having the proper tool and he either does the work with a less efficient tool, or if the proper tool is supposed to be around, he will spend a long time hunting it. The workman will seldom supply himself with a full set of tools, because some are needed so seldom that he thinks he can get along without them. But there are times when he needs one or more of these and he does not have them. This tool room, shown in Fig. 5, also provides a storage place for riddles, rammers and shovels, which, as a general rule, have to stand all kind of abuse because no definite storage place is provided.

The tool trays stored in the tool room are filled with sets of tools called for on the instruction cards and these are set on the molding and core benches as shown in Figs. 8 and 9. Odd tools are checked out by the workmen on the ordinary brass check system. When these tools are returned they are inspected by

Fig. 12—Brass Furnace and Floor of Brass Molds

the tool room attendant, and any needing repair or replacing are set aside and turned over to the mechanical assistant.

Two of the biggest labor-saving devices designed and put into use in this shop are the molding and core benches shown in Figs. 8 and 9. These benches were designed with a view of having a place for every necessary tool and all materials, and to have each thing within the easiest reaching distance, and a most convenient place for replacing.

By this arrangement and the following of the standard operation routines, practically all of the waste or lost effort, so common in bench molding and coremaking, is eliminated.

The utility of this molding bench was pointed out in a paper presented by the authors before this association at its meeting in 1914.

The principle of the arrangement of the core benches, Fig. 9, is similar to the molding benches. The hopper holds a large quantity of sand, thus allowing a large amount to be delivered to the bench at one time and yet to prevent it from being spread out in the way of the workman. The standard tool tray is placed at the right for convenience in reaching the tools. Being tilted, the tools can be easily seen and reached. At the left is the wire and rod box, off the working surface of the bench, yet easily reached.

These boxes of bent wires are brought from the stock room as ordered by the materials assistant. The empty plates are stacked on the lower shelf of the bench, while the small side shelf is used on which to set the core plate when being filled.

For cleaning the core boxes there is a waste holder for holding the kerosene-soaked waste with which to clean the box, and a compressed air hose with an attached blow gun for blowing out the dirt. The strike-off has its holder on the sand hopper directly in front of the worker, easy of access and can be replaced by throwing it into place. The instruction card holder is so placed that the card can be easily read by the worker.

By this arrangement of the bench, the coremaker has and keeps each thing in its place and loses no time in hunting for the tools, plate or wires needed. His whole time, for this reason, can be devoted to doing the actual productive work of coremaking.

Ovens and Core Storage

The oven equipment consists of one large truck oven, heated with an oil burner, and one portable, gas-fired oven. When the small cores are taken out of the oven they are set on the nearby cooling shelves of the rack, shown in Fig. 10. The upper shelves are devoted to stock core storage. As the orders are made up for the different molders, the cores are placed on trays, shown on the molding benches, Fig. 8, and are taken by the materials assistant to the molding benches or floors when they are to be used.

Some of the machines in use are shown in Fig. 11. The greater percentage of the standard patterns are fitted up for squeezer machine work, although the flywheels, pistons and similar work, are made on the stripping plate and roll-over machines.

The melting equipment consists of two Whiting cupolas and a Hawley-Schwartz brass furnace. A 5-ton Whiting crane commands the entire molding floor space. Figs. 6 and 7 show some of the large and small work which can be turned out by the students after a short period of instruction if the work is administered in the most efficient way.

The ideal of the constructional work is to convey to the student a knowledge of the best methods of foundry practice, to give him the ability to distinguish between good and bad practice, and to instill in his mind the methods used to investigate shop performances.

THE MECHANICAL ENGINEERING DEPARTMENT

By D. E. MILLER, '16

The first Student Branches of the American Society of Mechanical Engineers were founded by the parent society in the year 1908, at Cornell University, Ithaca, N. Y., and at Stevens Institute of Technology, Hoboken, N. J., and since that time the Student Branches have been installed in nearly all of the leading universities where the course in Mechanical Engineering is being taught.

The organization of this branch of the A. S. M. E. is patterned very closely upon that of the parent society, the aim of both being to aid the engineer in his work through the discussion of engineering subjects and the reading of papers upon subjects dealing directly with the engineering phase of the work. Of course the young engineer who is just now studying the elementary parts of the profession can not be expected to go into the deeper portion of engineering, such as would be taken up in a society composed of practical men who are out in the work, but the rudimentary things—the things upon which engineering is really founded—are subjects which are taken up and discussed at length in the Student Branch of A. S. M. E.

Occasionally open meetings are held at which some special attractions are staged, such as "movies," showing the manufacture of certain products, as for instance, Ford automobile, shoes, wire and galvanized goods, etc., and to which the public is invited. A number of these open meetings were held last year, and several very good ones are planned for this semester.

Although the Student Branch of the A. S. M. E. at Illinois is but six years old, being founded in 1909, it fast becoming an important factor in the work of the mechanical engineering students here, and is taking its place among the important organizations in the engineering school. A great deal of interest is being shown this year, and the men are taking hold with a will and boosting in every way possible. At the time of the M. E. Open House everyone "got behind and pushed," and the Open House of this year was certainly a decided success. Everyone who attended expressed themselves as having enjoyed the trip through the laboratories and shops, as well as being especially pleased with the souvenirs which were given away at the various points along the way. It was as much as a man's life was worth almost to secure a "Kewpie" at the latter part of the evening, so anxious were the people for this particular little paper weight. The crowds thronged the laboratories and shops and filled them to overflowing during the greater part of the evening. This opportunity of seeing the testing apparatus of the Laboratory, as

well as the whole shop equipment in operation is one which is not offered at any other time during the year, and a great many of the people of the two cities, along with the students, availed themselves of this chance when it was offered to them. Our laboratories are well equipped, in fact we have one of the most completely equipped M. E. laboratories in the middle west, and we are always glad to have people who are interested come in and see for themselves what we are doing here at the University. It is surprising how few people know what can be and what is being done in our shops and laboratories, yet they have the freedom of the University if they would but take it upon themselves to find out these things, and see what a wonderful University we have in the state of Illinois.

When the American Society of Mechanical Engineers began to establish the Student Branches in the various colleges and universities of the country, it was with the especial intent of affiliating the men in our universities and colleges and keeping in closer touch with them during their work as undergraduates, so that when they took up their chosen profession they might become candidates for membership to the parent society. The idea of the Student Branches was probably taken originally from the English Society and developed into its present state of organization.

Prof. Richards, of our own faculty, has made some suggestions for more closely connecting the student branches with the parent society and at the same time spurring the men in the student branches on to greater things in their efforts to win the prizes offered by the parent society. Whether his suggestions will be acted upon or not remains to be seen, but the Student Branch would be greatly benefited should the parent society decide to go ahead as Prof. Richards has suggested to them. His suggestions, it appears to the writer, would more closely affiliate the Branches with the parent society and stimulate the right sort of interest in the Student Branches.

A general survey of the doings of the Student Branch here at Illinois is given below, over the president's signature.

D. E. MILLER.

THE A. S. M. E. FOR 1915-16

The year opened with a business meeting on October the fourteenth, at which over a hundred mechanical engineering students were present. Mr. Day was elected to supercede Mr. Weinshenker as Junior representative since the latter did not return to school. A committee was appointed to do the publicity work for the society. This committee consisted of Becker,

Lundell, Gum, and Rosenkrantz. Another committee to look into the matter of securing the official student branch pin was appointed and consisted of Kurt, Minkema, and Mittendorf.

The next meeting was held on the twenty-eighth of October. At this meeting Mr. Hower, of the Willys-Overland Company talked about the sleeve valve motor. His lecture was strictly of an engineering nature and was enjoyed by all present. Almost 300 were at this meeting.

On November fourth Mr. George L. Willman, advertising manager for the Studebaker Corporation of America, talked on "Sales Engineering. Mr. Willman gave a very good address which was more than enjoyed by some eighty odd students who were present.

The remaining talks by outside men will be scattered throughout the first semester. The second semester, it is hoped, will be one of student talks. The program for the rest of the semester is:

Dec. 9—Maxwell Films.

Dec. 16—Val A. Fynn, Con. Engr. for Wagner Electric Co., St. Louis. (Designer of Unit Power Factor Motor.)

Jan. 13—Mr. Monett, formerly chief smoke inspector for the city of Chicago, now with the American Radiator Company. He will talk on "Smokeless Combustion."

Jan. 20—Mr. W. A. Blonck, senior of the firm of W. A. Blonck & Company, engineers of Chicago. He is the inventor of the boiler efficiency meter and other important boiler appliances. He will talk on "Efficiency Methods in the U. S. and Foreign Countries."

As previously stated, the next semester will be a semester of student talks. On the initiative of Prof. C. R. Richards the faculty has donated a splendid large trophy cup which is to be presented to the student giving the best original paper. The award is to be made as follows: First, the paper is to be given before the Society, then it is submitted to a committee consisting of five instructors in the M. E. department. The five best papers, according to this committee, will be passed on by a committee of five professors, who are members of the parent association but who are not directly connected with the department of mechanical engineering. The trophy cup will become the permanent possession of the winner.

In general the work of the Student Branch of the A. S. M. E. has progressed rather nicely this year, and it bids fair to be a successful year. More enthusiasm has been shown this year than for quite some time and it is earnestly desired that this be the case for the entire year.

G. C. Vandenboom.

NEATNESS, FORM AND ACCURACY

BY FRED B. SEELY

Associate in Theoretical and Applied Mechanics

When teachers of engineering studies differ so widely in the emphasis they place upon neatness and form or arrangement of written work,* it is not strange that some students find difficulty in properly weighting the various elements or factors which should be considered in presenting material on paper.

It is worth while, therefore, to call attention to certain fundamental facts, even psychological laws, an appreciation of which should help a student of engineering to present his written work so as to mean the most both to himself and to others who must examine and use it.

The superintendent of a steel mill stated a few years ago that his experience had led him to believe that many mistakes made in engineering, involving material presented on paper, (excluding the mistakes due to poor judgment) could be charged against the eyes. Not because of defective eyes or sight but because the material presented to the eyes failed to make a clear-cut, accurate impression.

This statement at once suggests the relation between neatness, good form and accuracy. These factors are often thought of as synonymous only with a pleasing appearance or artistic effect and therefore of little value in most engineering work. Furthermore, the idea that excessive time is required seems to be a common excuse for the failure to secure neatness and good form in the written material presented.

Very recently a squad of men obtained very good data for a stress-strain curve in a laboratory experiment. One of the men in order to save time drew, free hand, rather large circles around the plotted points instead of using an instrument; assuming that true circles would add neatness and good appearance only. The out-of-roundness of the circles was enough to distort his judgment, in drawing the curve and locating the elastic limit, sufficiently to have caused rejection of the material had the object of the experiment been to determine whether the material met the specifications.

As has been suggested, perhaps the chief value of these factors is their tendency to reduce error. Time in the long run will be saved.

It is often stated that if the principle and reasoning employed are correct, leading to a true answer or conclusion, the written

*The term "written work" or "written material" is here used to denote practically all material put on paper in connection with engineering work, such as: reports, problems, estimates, abstracts, drawings, correspondence, etc.

work should be satisfactory. The object, however, of material presented on paper is, in general, to present facts, ideas, etc., to others. It is not enough merely to have the written work correct. It does not function properly unless the *reader* gets a correct or accurate impression with minimum difficulty and waste of time. The facts must be presented so as to command attention, as far as possible, in proportion to their importance. In short, the written work should talk for or explain itself in its author's absence.

Correct written material is sometimes misinterpreted due to the fact that the desire or wish is father to inaccurate observation and thought. Correct material, too, may suggest different ideas to different readers depending upon the experience and upon the ideas previously suggested to the mind of the reader.

Nearly every person has a rather definite way and normal rate of taking impressions from written material through the eyes. When this material is presented in such a form as to interfere with this natural procedure irritation is the result. This is often only a subconscious experience unless extended over a long period when fatigue becomes apparent. This interference or resistance to the smooth and natural transmission of impressions tends towards error. That is, in order to register an accurate impression greater exertion is required in focusing and analyzing—concentrating—and the reader tends to make insufficient allowance for this added difficulty. He takes an impression and proceeds, the orrectness of the impression depending to a considerable extent, upon the appeal the material makes to the eye—its eye-attracting power.

To dismiss the problem by urging that one must observe and read carefully, while emphasizing an important and necessary habit, is neglecting to consider all the facts connected with the case. A person's inherent mental characteristics, of course, have much to do with his ability to take clear-cut and accurate impressions from any class of written work. But certain methods of presentation appeal to nearly every reader and give the minimum opportunity for taking inaccurate impressions. These methods being chiefly mechanical may be used to good advantage in any case.

Many such means may be employed to aid in accomplishing the desired result depending upon the nature of the material presented. These are, in general, applications of what may be called the *unit-impression* method. This consists merely in arranging written material so that each group of numbers, symbols, words, diagrams, etc., which has a meaning in itself, will stand out distinctly, attracting the eye, so that the proper group is

transmitted as the unit-impression. Advertising, of the more substantial sort, and some types of business correspondence often make use of similar methods with telling effect.

While riding on a street car recently, the writer attempted to read the advertising material printed on a large placard which was carried by a man walking on the sidewalk. The material, however, was presented in such poor form that the observer was able to get but a small part of the facts presented. The main facts could have been presented so as to have attracted the eye and given the observer an accurate impression.

A graph sheet containing several curves was prepared with great care, from reliable experimental data, for use in a designing office. On several occasions values were read by different persons from the wrong curve, the error in one case proving costly.

A designer once took the value for the cosine of an angle from the wrong column in a table, the error being carried through a large portion of a long series of computations before it happened to be detected.

Such mistakes are typical of many. There is no excuse for them and yet there is no absolute safeguard for preventing their occurrence. Errors are fraught with such large consequences that it behooves one to use any simple method which will help reduce them.

A laboratory class of graduate students, the members of which had had little training in getting experimental data, consumed two hours in preparing a form, for recording the data to be obtained, which would properly present the experimental data to a person not connected with the experiment. It took considerable time, in other words, to appreciate what the problem of formulating the data involved and to properly estimate or measure its difficulties. Practice and care are necessary to acquire ability along this line.

A reader sometimes little realizes that the arrangement of written material on a page decides for him the emphasis he will place upon the various parts. An idea may be made to look important when it is not. On the other hand a fact of great importance may be made to appear of little consequence. This is especially true when the material presented is new to the reader.

The writer has observed, in fact has arranged tests which indicate, that the preparation of a class on various parts of a lesson depends upon the eye-attracting power of the different parts. It is not difficult to find two technical books on the same

subject which differ widely in the appeal they make to their reader.

While neatness and good form help much in securing accuracy the fact that they lend authority to and inspire confidence in the material presented is of much importance.

Last year two students answered all of the questions on a final examination completely and correctly. It required, however, more than ten times as long to grade one as the other and even then it was difficult to feel the same confidence in the work presented. The reader may judge of the probable result if these papers had been applications for a responsible position.

In this connection it should be stated that material given out by the instructor should be prepared with these same ideas in mind.

A recent paper given before one of the engineering societies contains a statement of interest in this discussion. The author in discussing "The Investment Banker and the Engineer" states: "It is surprising to find the apparent lack of care with which many engineering reports are prepared. I may say that errors are very common and statements are not clearly made. . . . . Many reports which come to hand do not reflect credit upon the engineering profession."*

Much has been said in recent years about the importance of a command of good English to engineers. This should certainly include the ability to present material on paper so as to insure accuracy, inspire confidence and carry authority.

*Jour. Assoc. of Eng. Societies, June, 1915.

The only medal of honor awarded for rail joint products in the transportation department by the Panama-Pacific International Exposition at San Francisco was to the Rail Joint Company of New York.

The Wagner Electric Manufacturing Company of St. Louis announces the opening of an office in the Walker Bank Building, Salt Lake City. The office will be in charge of Mr. F. C. Morton, who for many years has been identified with the sale of electrical apparatus in this territory.

SOME MECHANICAL CONSIDERATIONS IN DESIGNING AND BUILDING ALTERNATING CURRENT MOTORS

F. N. JEWETT

Sales Manager of Wagner Electric Co.

Within the limits of this brief article, there can be indicated but a few of the more prominent mechanical problems affecting the design and construction of Alternating Current Motors.

Compromise and sacrifice are ever essentials in the solution of life's problems. So in engineering the skilled engineer must know what to sacrifice and where to compromise in producing results.

We will assume that the electrical engineer has provided a complete electrical design, specifying weight of sheet steel laminations slotted for the coils, which are to consist of a definite number of turns of a specified size of insulated copper wire. However, with the most perfect electrical design we are far from ready to build a motor. There must be co-operating conferences between the electrical and mechanical engineers.

Perhaps the first and most important problem will be the determination of proportion between diameter and length. For, the proposed motor may be built with a diameter relatively small as compared to the length. Or, the motor may be made relatively short as compared to the diameter. We are not here concerned about the electrical advantages or disadvantages of the two suggested shapes, though the electrical performance be affected.

The mechanical engineer will select that proportion which provides the most economical use of material with the least required machine work and labor expense. The Electrical Engineer may wish quite a different proportion to get the best possible performance characteristics. But, there are already in the market other makes of motors, perhaps giving good satisfaction; and which sell at well established and known prices. Compromise and sacrifice become to some extent masters of our engineers. The cost of the finished product, within narrow limits, must approximate the market. The management of the Company may aim to either undersell the market, to exactly meet the market, or may plan to build just a little better motors than the market affords, and, therefore, charge just a little higher price than other makers.

The engineers in conference then decide how much of ideal performance characteristics must be sacrificed, in arriving at that proportion of diameter to length which will give the maximum

obtainable performance characteristics, consistent with the requirements of the commercial end of the business.

Speaking broadly, it may be noted that most of the well known and larger makers of motors, of the type under consideration, have made rotor diameter approximately equal to the thickness of lamination parallel to the shaft. (See Figs. 1-2.)

After the electrical and mechanical engineers have determined the general proportions compatible with good performance and allowable cost, the mechanical engineer may proceed quite independently of the electrical engineer.

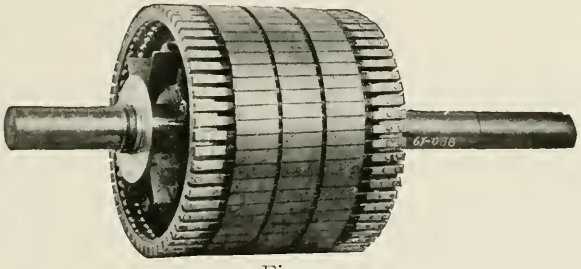

Fig. 1
Typical Squirrel Cage Rotor, Wagner Motor

Perhaps the first problem to be solved in the mechanical design is shaft diameter. This will be affected by the character of the steel to be used. For commercial reasons the engineer will probably be compelled to sacrifice his desire for absolutely the highest grade and will compromise on the best grade permissible, ultimate cost considered. Knowing then the character of steel

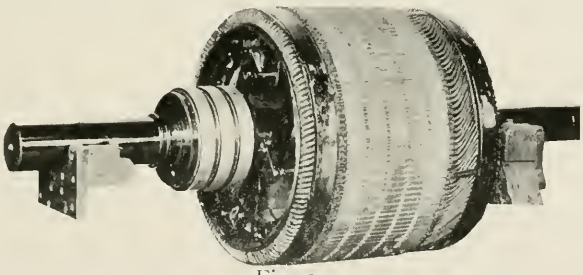

Fig. 2
Typical Wound Rotor, Wagner Motor

to be used, the determination of shaft diameter to be a simple problem, given the speed of rotation, the horse power to be transmitted, and also the maximum torque. Still other factors enter, however. For example: The overhang of pulley exten-

sion, key ways which reduce the effective strength, as well as length between bearings.

It will be noted that a compromise must again be effected. The toughest steel permits minimum diameter. In the bearings this may require impossible length of bearing to avoid too high pressure per sq. in. of projected area. As ample bearing area is essential, as will be shown later, a larger shaft diameter becomes desirable, and, hence, a lower grade of material may be not only permitted, but preferred.

Having determined the shaft diameter, and the electrical engineers having determined the density at which the magnetic material will be worked, the superficial external rotor area may be

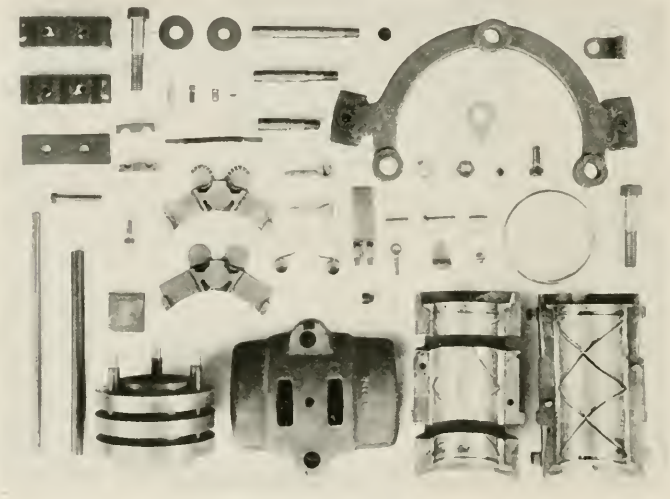

Fig. 3
Complete Split Ring Assembly, Brush Holder Parts and Split Type Babbitted Bearings

determined, bearing in mind the predetermined proportion between diameter and length, so that we arrive at the thickness or number of laminations to be used.

Next, a method must be provided for holding the rotor laminations to the shaft. In smaller motors it is usually found sufficient to punch a hole in the center of each sheet just large enough to permit of the assembly of the rotor laminations directly on the rotor shaft itself. By providing a spiral keyway and key in the shaft and notching the central hole through the rotor punching, the "skew" noted in the illustration (See Fig. 1) is obtained and the keyway on the shaft transmits torque to the

shaft. In Fig. 7 will be seen both stator and rotor laminations and punch press.

Bolt holes are provided through the rotor laminations and against each end of the assembled rotor laminations, cast iron clamping flanges are bolted through these holes. These cast iron clamping flanges serve two purposes:

1) Flanges serve to rigidly bind together the rotor laminations, and also
2) Provide at their periphery a support for the ends of the rotor coils.

This support is plainly seen under the ends of the coil in Fig. 2.

For larger motors it is found more economical in the use of material, and better rotor ventilation is also secured, by providing cast iron spiders which are keyed to the shaft and on which the rotor laminations are assembled. A large central hole is punched out of the rotor laminations and the central punched out portion may be used for rotors in smaller motors. The rotor spider is provided at one end with a clamping flange and peripheral coil support quite similar to the flanges above mentioned.

After the rotor laminations have been assembled on the cast iron spider, a circular clamping flange is bolted up to the free end of the spider. The laminations then are clamped between the two flanges and are securely held by bolts which go through the laminations from the spider flange to the circular flange. This spider construction also gives the added advantage that the shaft may be removed and a new shaft substituted in case of accident or shaft damage. When the rotor laminations are assembled directly on the shaft, it is much more difficult and sometimes impossible to substitute a new shaft.

The coil end supports on the flanges mentioned in the previous paragraph may be proportioned only after the coils have been laid out. If the winding is to be of the type commonly called "wound rotor" type, we must lay out the projecting ends long enough so that the coils may cross over and under each other and span the specified number of slots.

Having determined the minimum projection of the rotor coils beyond the laminations, we can then tell how far the supporting surface on the rotor clamping flanges must extend, in order to support the end turns of the rotor coils.

Herein will be found the explanation of the extra length of a two pole motor over that of a motor of a greater number of poles. Extra length is required because of the greater span necessary for the end turns.

It will be immediately apparent that some form of external

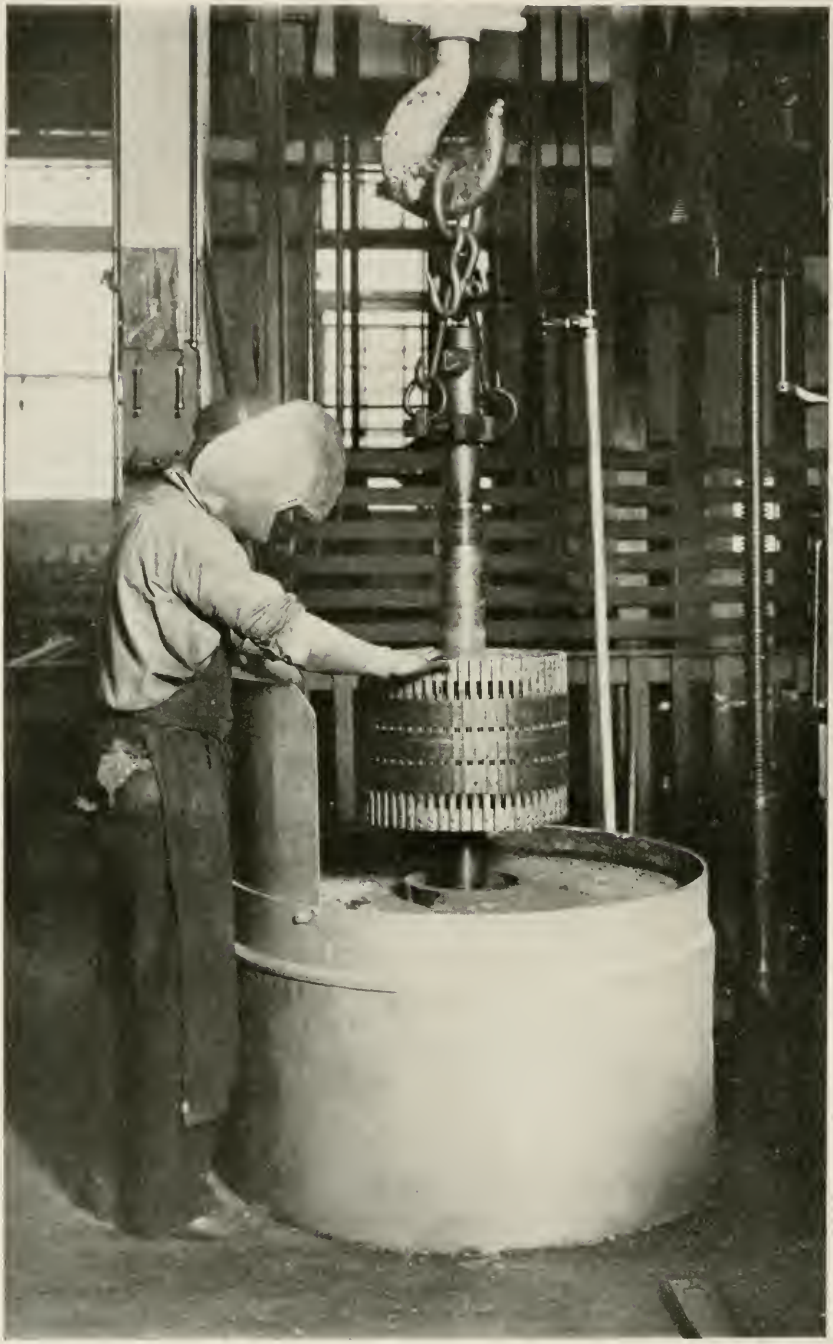

Fig. 4
Method of soldering rotor bars to end rings. Incidentally note "Safety First" helmet to protect workman.

banding must be used to counteract the effect of centrifugal force on the end turns. In order to provide rigidity and permanency to the banding (See Fig. 2), a high grade of steel wire is machine wound around the external surface of the end turns which are thus held solidly against the previously mentioned clamping flange coil supports. Bearing in mind the heavy centrifugal force due to rapid rotation, rigid and well supported connections must be provided between the several phase groups of coils and slip rings shown in Fig. 2.

The slip rings in turn furnish an exacting problem in mechanical design. Each slip ring must be securely and rigidly held to the motor shaft, yet each must be efficiently insulated therefrom, and from each other. The highest quality of non-compressible

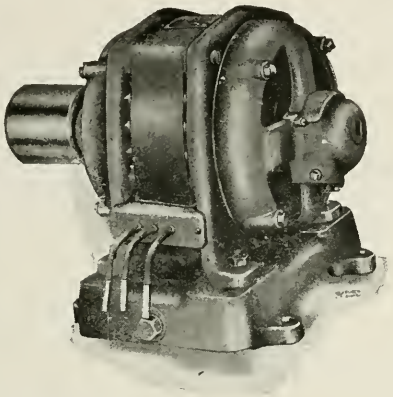

Fig. 5
Skeleton or Frameless Type Showing Stator Core Periphery Exposed.

insulation is required. Skilled and accurate workmanship, as well as design, are demanded in order to avoid either insulation break down or eccentricity of the rings on the shaft. Eccentricity of the rings causes rapid wear and early repairs.

In Fig. 3 will be noted a complete set of slip rings assembled and ready for mounting on the shaft. Near the slip rings will also be shown the heavy conductor bars which pass through holes provided in the ring mounting in order to make connection to each of the rings.

Some makes of motors have been provided with hollow shafts and the connections between slip rings and phase groups of rotor coils were made through the hollow shaft. This form of construction, however, has now been entirely abandoned in favor of the construction illustrated and above described.

If the squirrel cage type of rotor is to be used the engineer

must decide how to fasten the ends of the rotor bars to the end rings, and type of end ring construction.

Some makers prefer the construction illustrated in Fig. No. 1 in which the rotor bars are drilled and double copper riveted to cast brass end rings of ample cross section to carry the rotor current, and, at the same time, give just that amount of resistance essential to good starting characteristics.

After the rivetting has been completed, rotor end ring is dipped in molten solder to insure best electrical connection between rotor bars and end ring. It will be noted in Fig. No. 4 that the shaft is not dipped in the hot solder, thus avoiding drawing the temper of the shaft.

Several other methods of squirrel cage motor winding are used, the more common being:

a) After the rotor bars have been placed in position in the rotor slots the ends of the bars are placed in a mould into which is poured molten brass. The brass end ring is thus cast with the ends of the rotor bars embedded in the casting.

As performance characteristics of the motor are quite largely dependent upon the uniformity and completeness of connection between rotor bars and end rings, it will be apparent that the process of casting the end rings on to the rotor bars may prove very unsatisfactory, if the joints, so formed between the bars and the end ring, are not uniform throughout the same motor and also uniform in different motors supposedly similar. Because of the difficulty in securing uniformity in the joints, this form of construction has been adopted by one or two small makers only.

b) For quite a similar reason electric welded joints between motor bars and end rings are little used.

As is well known copper is one of the most difficult metals to satisfactorily and certainly weld. Metals which can be satisfactorily and dependably welded are those which soften gradually under the influence of heat and which assume a plastic state before becoming liquid. Copper when heated seems not to possess that plastic state so essential in welding. When copper is heated it seems to have a critical temperature at which there is a sudden and almost immediate change from

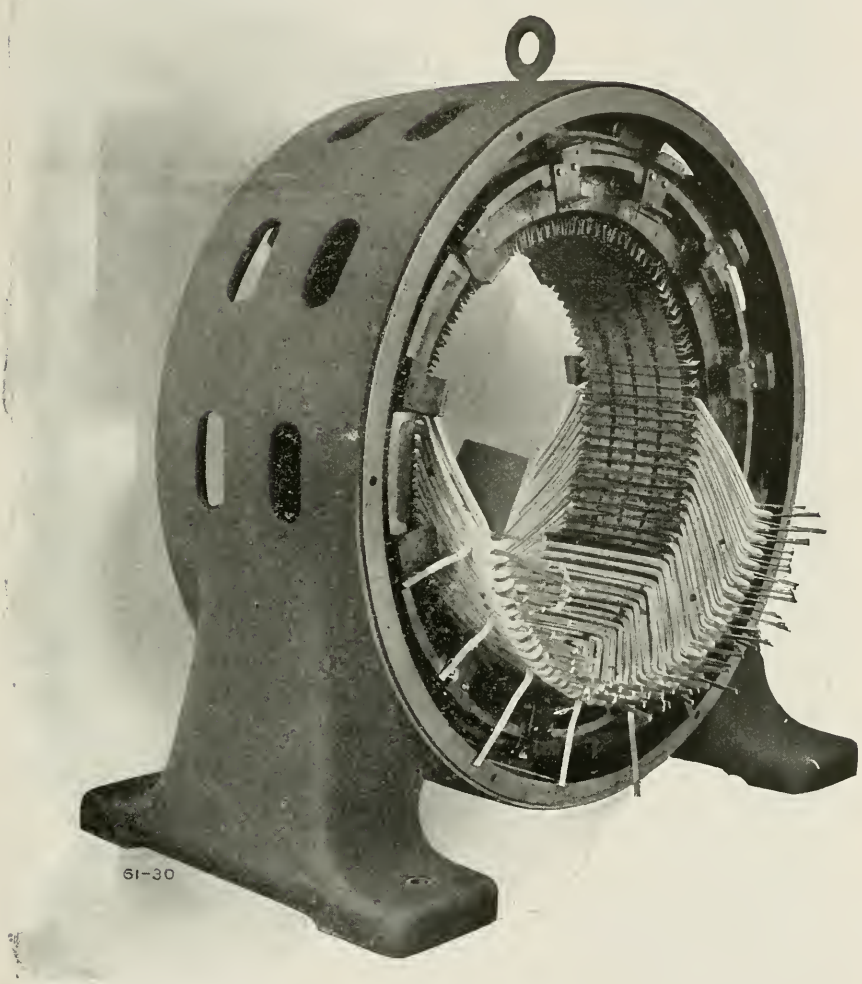

Fig. 6
Stator Frame, and core, with coils partly installed. Wagner Motor.

solid to liquid state. Unless the greatest of care and skill are exercised, attempts at copper welding are apt to result in unexpected shape distortion, and even cross section reduction, which will seriously interfere with the uniformity of conductivity and resistance needed in the completed squirrel cage winding.

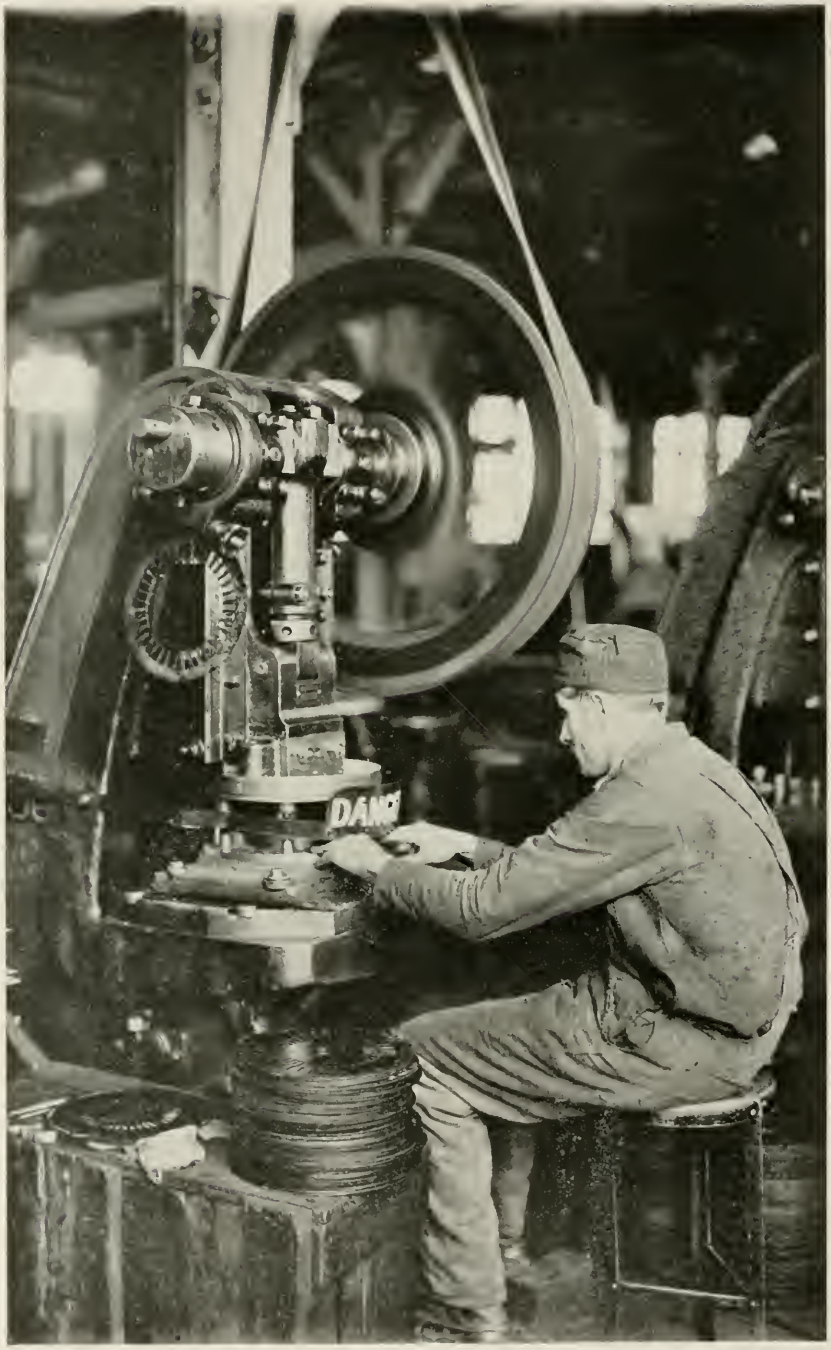

Fig. 7
Punch Press separating rotor lamination from stator core lamination.
Note "Safety First" Guard.

c) The double rivetted and hard soldered construction illustrated in Fig. 1, serves most admirably for motors for the higher frequencies above 40 cycles, where more rotor resistance is required in torque production than is needed in the lower frequency motors. In motors for lower frequencies, the rotor resistance must be kept much lower and therefore an end ring construction must be provided which will give the maximum conductivity.

To secure this, circular laminations are punched from copper sheets, with holes corresponding to the punched slots in the rotor core laminations. The required thickness of copper laminations are assembled over the ends of the rotor bars and well pressed together. The rotor bars are previously split, and, after assembly of the laminated copper end rings, a bronze wedge is driven into the split ends of the rotor bars. This serves to expand the ends of the bars to give the maximum contact between bar and built up laminated end ring. After the assembly is complete the built up copper end rings are then dipped into the solder as illustrated in Fig. 4.

The solder serves not only the mechanical purpose of holding the entire assembly intact, but also serves the electrical purpose of securing the maximum conductivity between the bars and end ring. After cooling the surplus metal is turned off in a lathe and the cross section of the end ring finished exactly to the predetermined dimensions. This construction secures not only minimum as well as uniform resistance, but also assures maximum life.

d) For the higher frequency motors some makers have used a somewhat similar construction to that just described. Punched sheet end rings of metal having higher resistance than copper are placed over the ends of the rotor bars and grouped into several grouped layers. This construction gives sufficient resistance for the higher frequencies and at the same time gives ventilation between the groups of end sheets, assisting in cooling the squirrel cage. A strong objection to this particular construction is that in cases of unexpected overloads and softening of the solder, the mechanical strength of the assembly is insufficient to remain permanent.

Having hastily touched on some of the more important features of rotor design and construction, and having necessarily omitted many minor features, stator construction may now be considered.

Knowing that the magnetic lines must pass from stator core face to rotor core face, and vice versa, it will be immediately understood that stator core face must be equal to the rotor face; and the air gap, or space between the two faces, must be as uniform and as small as possible considering the best expected life of the motor bearings. Uniformity of air gap will be depend-

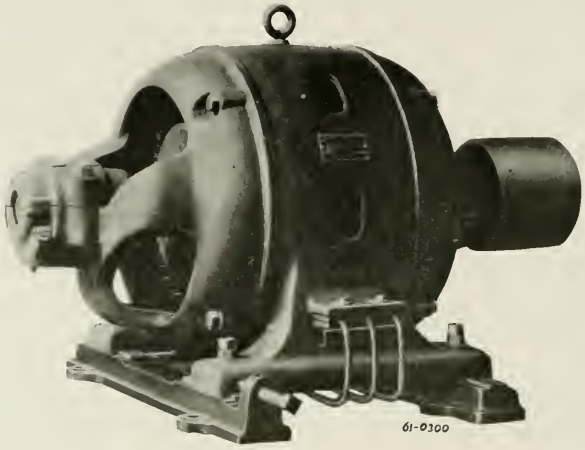

Fig. 8
Wagner Self Starting Polphase Motor.

ent upon attainable accuracy in machine tool operation and assembly workmanship.

Here again there is confliction between mechanical ideals and electrical ideals. Electrically speaking the minimum attainable air gap is desirable because of the reluctance of the magnetic lines to pass across the air gap. Mechanically speaking, howeverfi a large air gap is ideal because all bearings are bound to show wear in the course of time. In commercially practical construction methods, a maximum machine and assembly accuracy only are possible. The electrical and mechanical engineers must compromise and each sacrifice something in order that a workable construction may be concluded. In Alternating Current Motors the usual air gap between rotor core face and stator face is expressed in thousandths inches and rarely in hundredths, so close and so accurate are the limits of modern shop practice.

The mechanical engineers having decided the minimum air gap permissable, and the electrical engineers the radial thickness

of stator required, the outside diameter of stator core, if round is quickly determined. It will be noted that most makers prefer circular external stator core surface, although some makers provide an approximate square and others polygonal shape. The choice of shape will depend upon decision as to method of supporting stator core. If it be considered desirable to rivet end castings and feet to the core, then the periphery of the punchings may be entirely exposed and approximately square construction used as in Fig. No. 5 or similarly a polygonal periphery may be chosen. This construction has various obvious disadvantages; difficulty in securing good looking finish and expense of same;

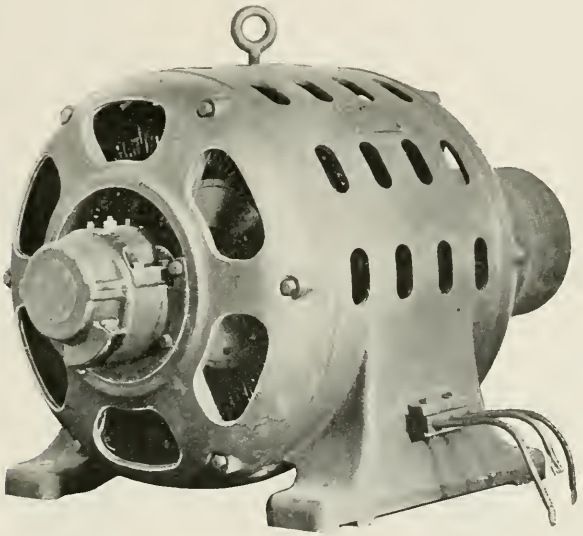

Fig. 9
Large Polyphase Motor. Wagner.

possible distortion from rough handling, impossibility of repair. Nevertheless this construction has had and still has considerable vogue. A much preferred construction, however, provides a cast iron "frame" which serves both as a rigid mechanical support for the end plates in which are mounted the bearings and consequently which also support the rotor. This general type of frame is illustrated in Figs. 6-8-9.

It will at once be apparent that the circular shape of the cast iron frame readily lends itself to accurate and secure assembly of the stator punchings, as well as providing economical machine tool operations. It will be observed that the frame casting can be completely machined in either vertical or horizontal boring

mills with the exception of the bottom of the feet, and a few drilled holes. As soon as the boring operation is completed, a jig may be placed on the turned shoulder, provided for the reception of the end plate, and a multiple spindle drill will quickly and accurately provide the holes not only for holding the end plates securely on the frame, but also the holes for the through bolts. These through bolts serve not only as guides for the accurate placing of the laminations in the frame, but also to draw against the laminations the cast iron clamps which hold the laminations together, preventing them from turning in the frame, since the torque developed in the rotor re-acts in equal

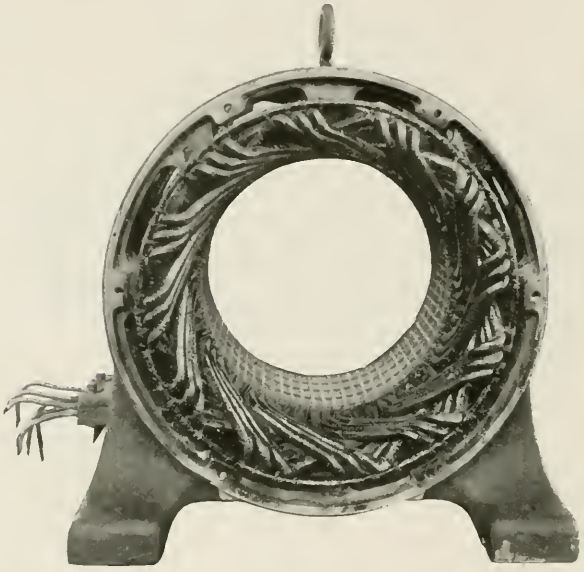

Fig. 10
Completed Polyphase Stator. Wagner.

amount in the stator core and which therefore must be securely held.

The same turned shoulder also serves for accurately jigging the frame in a large milling machine (or in some works a planer) for accurately surfacing the feet in a plane exactly parallel to the motor shaft; at the same time machining the recesses in the feet, provided to fit accurately on the rails or subbase on which the motor will ultimately rest.

Fig. 6 clearly shows the space between the periphery of the stator laminations and the interior of the cast iron frame. This space is valuable for efficient ventilation and consequent cooling of the active stator material. Heat dissipation is plainly a prob-

lem for the mechanical engineer rather than the electrical engineer. Fig. 6 and Fig. 10 clearly show the spaces provided between the periphery of the assembled laminations and inner surface of the frame to permit of the free circulations, but also radially between the laminations in several places. The number, size and location of openings in the cast frame also materially affect efficient ventilation.

With this form of cast frame construction, should the motor be accidently dropped and the frame cracked, it is possible to replace the stator core and coils into a new frame casting.

In the installations of the stator windings it again becomes necessary for the stator coils to span a given number of shots and to cross over and under the neighboring coils as is clearly illustrated in Fig. 6 and 10.

The stator coils will then project from the stator laminations a considerable distance toward the end plates. See Fig. 11. Since the end turns of the stator coils do not rotate, it might not appear essential to give support to the projecting coils. However, under conditions of sudden overloads, possible short circuit or heavy starting currents, there are forces generated in the end turns tending to badly distort them. Hence there must be provided effective support for the projecting coil ends. One solution of this problem is clearly shown in Fig. 10 where a rigid ring encircles the coil projections and to which each coil is securely and permanently tied. This is a patented construction and consequently is used by a limited number of manufacturers only. Some makers depend only upon the rigidity of the coils, which are made as stiff as possible. These, under unusual stresses of unexpected overload or heavy starting conditions, are apt to vibrate to such an extent as to give way where the coils enter and leave the core slots.

Knowing now the distance required between bearings to provide rotating space for the completed rotor; and also space necessary to provide ample room for the stator coil end projections, the end plates (or "end bells" as some designate them) may be designed. The accompanying cuts clearly show the method of attaching the end plates to the stator frame housing, which in the several illustrations is practically identical. The end plates must be designed not only to provide the required space between the end plates, but must also provide housing and support for the bearings. At the same time the aesthetic sense for beauty must be satisfied.

A general globular shape for the entire motor may have been predetermined, in which case the frame will be more spherical than shown in the illustrations and the end plates must then

conform to the same spherical lines. A general straight line construction may have been chosen. See Fig. 5. Figs. 8, 9 and 11, however, show a very pleasing design which is a compromise between the straight line and the spherical.

It is self evident that the end plate has several important functions to perform.

1) End plate must be rigid enough and strong enough to stand the strains incident to transmitting the full torque of which the motor is capable. The design of the end plate might be simpler did we know the direction in which torque is transmitted, or, in other words, in which belt strain occurs. The motor may be installed so that

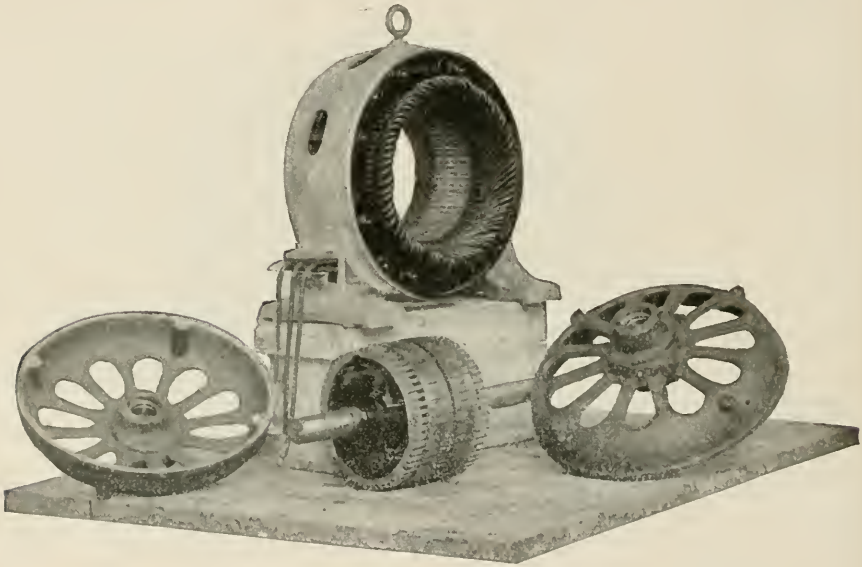

Fig. 11
Poly-Phase Motor (Wagner) With End Plates and Rotor Removed.

the belt runs straight downward, straight upward, horizontally, or at some intermediate angle. The end plate must then be prepared to resist the full pull from any direction normal to the shaft.

2) There must be provided ample openings to secure ventilation of the active material and, not only must the openings be ample in size, but they must be correctly proportioned and located to secure maximum ventilation.

3) As the entire weight of the complete rotor is supported by the end plates only, it will be necessary to consider, not only strains normal to the shaft, but to also consider possible jars and bangs incident to handling and shipping the motor over the average railroad. Since it is impracticable for the manufacturer to provide a personal attendant for each motor while in transit it is quite likely that the freight handlers will place the motor in the freight car with the shaft parallel to the track. In this event the ordinary starting and stopping of freight trains, to say nothing of switching, is more than likely to cause a tendency for the stator to travel leaving the rotor behind, due to its own inertia. The end plates may then be called upon to take up very heavy jars from the rotor, hence the necessity for rigid and strong construction.

In selecting bearings, the engineer has open to him a wide choice, not only of types of bearings, but of materials. The market is, however, generally standardized as to one bearing feature. All motors are provided with ring oil bearings with the exception of a few equipped with ball or roller bearings. The ring oiler has been used for so many years and is in every way so entirely satisfactory, that little space need here be devoted to it.

For smaller motors experience has proven the solid sleeve type of bearing as illustrated in Fig. 12 to be entirely satisfactory. This type of bearing is not only economical in first cost, but is quite universally used and rarely gives any cause for complaint when oil well is supplied with enough oil to permit the ring to dip therein.

In larger motors, where shafts are larger and bearing speed consequently runs higher, it is found advantageous to supply split bearings and split bearing housings clearly indicated in Figs. 3-8-9. Fig 4 shows a split type of babbitted bearing with the usual grooves provided for the oil rings, of which there are two in this particular bearing. One of the oil rings may be noted next to the bearing. The construction shown in Fig. 3 permits of the removal of the bearing shell which may be rebabbitted by any first class mechanic.

Attention is here called to the careful arrangement of oil grooves cut into the babbit to provide for distribution of oil to all parts of the bearing. A careless arrangement of grooves is sure to result in bearing trouble. Fig. 9 shows a type of construction in which the bearing housing is not integral with,

but is separate from the end plate and may be removed entirely for repairing or replacing bearings or even bearing housing.

Attention here is called to the cap over the end of the bearing housing, Fig. 9. This cap is provided to make the bearing dust proof, a practice which is frequently called for, in installations where the atmosphere is heavily charged with dust particles

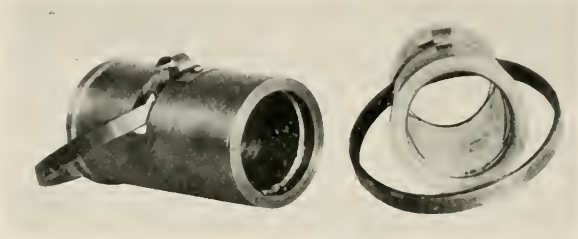

Fig. 12
Ring Oiling Sleeve Type Motor Bearing.

which may be injurious to the bearings.

As noted above, the air gap between the rotor and the stator is very small. It is self evident then that little or no wear can be permitted in the bearings of an Alternating Current Motor. Nor is it practicable to provide any adjustment for wear. Adjustment, in the hands of the unskilled, would only result in irreparable damage to the motor. Undue or rapid wear of bearings would be equally fatal.

The engineer then must be most liberal in his design of bearing areas and must be particular in the choice of materials used. In the sleeve type of bearing he must select only the highest grade of phosphor bronze and in the babbited split type of bearing only the highest grade of hard babbit metal may be used. The several illustrations clearly show that the bearing housing has been given ample strength to withstand the strains above mentioned. The oil well into which the oil rings dip, is within the lower bulging portion of the housing. The upper half of the housing held on by bolts, is more than a mere cover for the bearing. In some cases the maximum motor torque must be resisted entirely by the bearing housing covers.

That the engineer has been successful and generous with bearing design and material, is attested by the hundreds of thousands of Alternating Current Motors in use throughout the world, all operating with rare and infrequent replacements. For some special types of small motors for unusual applications, ball or roller bearings are successfully used, though infrequently.

In the majority of cases motors are belted to the driven

machinery. Since belting has a way of stretching with use, some form of adjustment must be provided between motor and driven machine. As the motor is usually smaller and lighter and more conveniently moved than the driven machine, it is customary to provide means for tightening the belt by moving the motor away from the driven machine. Cut No. 5 shows the motor mounted on a solid cast iron base with adjusting screw in the foreground.

For smaller motors, the solid cast iron base is preferable to but more expensive than "rails." Fig. 8 clearly indicates rails, guides and adjusting screws. It will be noted that the rails, once placed, may be fastened securely to the floor, foundation, wall, or ceiling as the case may be. Practically all motors are now built so that they may be set upon the level floor. Or, they may be mounted on the side wall or even hung upside down from the ceiling. From Fig. 8 it will at once be apparent that the rails are of the box type, i. e. hollow, rectangular in cross section. They must be sufficiently rugged to sustain the motor in any of the positions mentioned. An examination of Figs. 5, 8, and 11 will indicate that the end plates may be rotated on the frame 90 degrees, either to the right or to the left, or 180 degrees. This is of course necessary in order that the oil well may be maintained in an upright position regardless of the mounting of the motor.

Since any motor may be mounted in any one of the three positions mentioned, the basic reason for the circular shape of motor end plates is immediately evidenced. Further, the reason for the most careful and accurate machine work also becomes evident, since the rotor must be maintained central in the stator in each of the several possible positions of end plates.

Larger motors as indicated in Fig. 9 do not need to be arranged for wall suspension, hence it will be noted that there are six bolts provided to hold the end plate to the frame. This motor may not be wall mounted unless it is specially arranged for at the time motor is built. It may be hung from the ceiling, however.

From what has been said, it is apparent that at every stage of designing and building, and in many little details which have necessarily been omitted, the engineer and the builder are compelled to sacrifice many details and must continually compromise between the practical and the ideal, in order to provide a finished product superior to competitive articles, and at the same time sufficiently within price range of the competition as to permit sales in sufficient volume to warrant economical shop methods and production.

It will be noted that while the purely electrical engineering is of the greatest importance, yet the mechanical design may not be overlooked or treated carelessly.

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THE TECHNOGRAPH, Champaign, Ill.

EDITORIAL

As the readers of the Technograph glance through this issue they will probably observe that the articles are devoted chiefly to mechanical engineering subjects. The policy of the Board this year is to give an issue of the Technograph to each of the departments of the Engineering School, and to subjects pertaining to that department. We thoroughly believe that we have the best Engineering College in the United States and are out to boost it and to tell outsiders what we have. The article on the Foundry of the University is worthy of your attention, because it has been stated by authorities that this foundry and its methods are from ten to twenty years farther advanced than most foundries in this country. That the students have grasped the spirit of the department is shown by the class of show put forth by them at the recent M. E. open house.

There has been a movement among some of the senior engineers of this college toward the adoption of corduroy trousers as the official garment and distinction mark of the senior engineers —following the practice of several other schools. So far only a few are wearing the corduroy, whereas the whole senior engineering class should get behind the movement and settle it definitely either one way or the other.

This year the Ceramics department which was formerly connected with the Science school, is now a part of the engineering college. And according to the policy of the Board, the Ceramics Society is entitled to representation on the Board. C. Treichel '16 and J. L. Crawford '17 were the men selected for the Board. We heartily welcome the newcomers.

DEPARTMENT NOTES

RAILWAY CLUB NOTES

The annual feed for the club was held Friday, October 8th, and attended by about fifty future railroaders. The speakers of the evening were Mr. A. F. Comstock, Mr. E. G. Young, and Mr. E. R. Duesnup. Mr. Comstock advocated that the members of the club should take an active part in each meeting or they would not be getting the full value of their membership. His

reason for advocating taking a prominent part in the meetings was that to be successful, engineers as well as lawyers should be able to think and talk on their feet. Mr. Young spoke of the purpose of the club and welcomed any one that was interested in railway work to join whether they were members of the department or not. Mr. Dewsnup spoke of the feeling of self-reliance that a railway man must build up if he expects to succeed in the railway world. Another requirement of a successful railway man was the exercising of diplomacy. After the speeches all enjoyed the doughnuts, cider, and apples, while old friendships were renewed, and new ones made.

On Nov. 5th, Mr. Raymond S. Zeitler gave an interesting and instructive talk on Self-Propelled Cars. According to Mr. Zeitler many steam railroads could use this type of cars to advantage on their branch lines, while the electric railroads could use it on extensions that would not pay with the line electrified.

THE C. E. CLUB

On Firday evening, October 15, the C. E. Club held its annual feed in Engineering Hall. Short talks were given by Professor I. O. Baker of the C. E. department and by Mr. H. E. Babbett of the M. and S. E. department. In spite of the fact that the meeting was held the same evening as the M. E. open house, a large number of C. E's attended.

On November 5, a meeting was called in order to elect a junior representative to the Technograph board and to arrange for future meetings. The club decided to meet in Engineering Lecture Room on the first and third Fridays of each month. Most of the talks and papers are to be presented by students. At times, open discussions on engineering topics are to be held. All C. E's are urged to come out and take part in the discussions. The question of taking Saturday inspection trips under the direction of a faculty member was brought up and favorably received.

W. A. HEMMELBEICHER.

MINING SOCIETY NOTES

The Society held its first meeting on October 5, at which time the following officers were elected:

Harold Willson—President.
N. M. Morris—First Vice President.
R. R. Kraft—Second Vice President.
M. J. Reed—Secretary-Treasurer.

Members of the Faculty of Mining and the mining students

spent a very enjoyable evening as the guests of Professor and Mrs. H. H. Stoek on Oct. 19. Many matters of interest to the Mining Society were discussed and plans for making the Society a real live one were received and discussed with enthusiasm.

Mine Dynamometer Car

Mr. O. C. Callen of the Faculty of Mining of the U. of I. lectured before the Mining Society on "A Dynamometer Car for Use in Mines." This car is an adaptation of the well known railroad dynamometer car to mines. By its use much valuable information in regard to mine haulage, such as draw-bar pull, speed, distance, location, volts, amperes, brake application, and possibly grade can be obtained, which heretofore has not been available. In this respect it fills a want long felt by mining engineers all over the world. Prof. H. H. Stoek, Mr. A. C. Callen, of the Faculty of Mining, Prof. C. E. Schmidt, head of the R. R. engineering department of the University of Illinois have developed the idea and perfected the plans for such a car. They have been assisted all through this development by the criticisms and suggestions of some of the most prominent engineers of the United States. All that is needed now is the money to build the car. This car will make one of the latest advances in mining practice.

Moving Pictures of Mining Operations

A most entertaining lecture was given by Mr. H. I. Smith of the U. S. Bureau of Mines on Nov. 2, under the joint auspices of the Department of Mining and the Mining Society. The lecture was on Anthracite Coal Mining and was illustrated by four reels of moving pictures, which were loaned by the United States Bureau of Mines for this occasion. The pictures have been on exhibition at the fair at San Francisco during the summer where they attracted large numbers of visitors. The methods of mining, hoisting, and preparing the coal and the methods of testing for explosive mine gas were shown in the realistic manner only obtainable with moving pictures.

Prof. L. E. Young of the Department of Commerce gave an interesting talk to the Mining Society on "Some Problems in Mining Economics." Some of the questions he discussed were, "Should There Be Secret Ore Reserves." At a time of inflated market value of a metal, should the richest ore be mined, thus increasing the profits of the company enormously but probably temporarily, or should poor rock which has become workable are now that the price of the metal is high, be worked and the richest ore saved for a time when the market price is down, or

should both kinds of ore be mined in a manner which will be the most economical in the long run."

The Mining Department has received complete sets of photographs on the Preparation of Coal, and the Mining and Concentration of Joplin Zinc ores. These photos show the latest developments in these two fields of mining. They will be used in the lantern in connection with the regular courses in mining.

The Mining Department has been carrying on some tests for the Illinois State Mine Rescue Commission on a storage battery for use in a miner's electric lamp.

HAROLD WILLSON.

M. E. SOCIETY NOTES

At the first meeting of the society, October 6th, announcement was made of the offering of a handsome silver loving cup, by the professors of the department, for the best original paper presented before the society. The following letter from Prof. Richards to the president of the society will explain:

Mr. G. C. Vandenboom,
University of Illinois.

MY DEAR MR. VANDENBOOM:

To stimulate interest in the work of the student branch of the A. S. M. E. through the presentation before the society of carefully prepared original papers on mechanical engineering subjects, the professors in the Department of Mechanical Engineering desire to announce that for the current year, 1915-16, they will offer a trophy cup, to be awarded to the student member of the society who presents the best original paper during the year, subject to the following conditions:—

1.—The competition is open to all undergraduate student members of the A. S. M. E.

2.—The papers submitted are to be original; that is, they must present the results or a record of some experience of the author, or some investigation, design, or research conducted by him. A research may include the collation and reduction of data or information secured through a search of engineering literature, if due credit is given the sources of information.

3.—All papers submitted in competition are to be read by the author at some regular meeting of the society.

4.—Papers must be written in legible long-hand or typewritten, on standard 8½"x11" paper, and bound in manilla folders, properly labeled on the outside with the subject, author's name, and date of presentation.

5.—A preliminary examination of all papers submitted in this competition will be made by a committee of five of the younger instructors in the Department of Mechanical Engineering, who will select what they think are the five best papers. These five papers will be submitted to a committee of three professors in the University, members of the A. S. M. E., not connected with the Department of Mechanical Engineering, who will make the final award.

I should be glad if you will give due publicity to this matter, so that all members of the society will be familiar with the terms of the competition.

I desire to say that if the results of this competition are entirely satisfactory; that is, if there has been reasonable evidence that the offering of the prize stimulates great interest in the work of the society, we shall be glad to continue this competition from year to year; if on the other hand the results of this effort seem to be unsatisfactory, we shall probably withdraw the offer of a prize after one year's trial.

Trusting that this will accomplish the purpose desired by all of us, I am

Very cordially yours,

C. R. Richards,

Professor of Mechanical Engineering.

The cup is a handsome sterling silver cup standing about a foot high. The winner's name will be properly engraved on the cup.

With the offering of a material reward for good original work it is expected that members of the society will be more than willing to present good papers.

The second annual M. E. show, which was held the evening of October 15th, was a success from all viewpoints. Approximately five thousand people passed through the Mechanical Engineering Laboratory and the old Armory. The exhibits created much interest. In the M. E. Laboratory the engines were running and visitors were transported over the mass of whirling machinery on a platform suspended from the crane. The 60 H.P. Peerless motor on the test block was the center of attention. In the Machine Shop as well as in the Power Laboratory the gas engine proved its popularity. One of the twin cylinder engines which are manufactured in the Shop Laboratories ran throughout the evening and attracted crowds of people. Another engine was being erected by students and parts of other engines under construction were exhibited for inspection by the visitors. The Inspection Department of the Machine Shop with its stock of devices for making accurate measurements was an innovation to most of the people. In fact the exhibits were all very instructive. A heavy duty drill sank one inch holes in cast iron at the rate of forty inches per minute. The hydraulic testing machine designed by Prof. Moore of the T. and A. M. Department and built in the shops was operated by students, stretching, bending, and crushing specimens of steel, iron, and wood. An automatic screw machine turned out cap screws without the touch of human hand. Different processes of machinery were demonstrated on lathes, milling machines, grinders, and drills. Efficient and non-efficient methods of working were shown on a simple lathe job, so that the distinctive features of each method were evident. In

the Forge Shop a heavy punch press was at work pressing souvenir ash trays. The Oxy-Acetylene welding outfit was used in cutting odd shapes from heavy steel plate, and welding together broken parts of machines. The steam hammer attracted much attention by the powerfulness of the blow which it delivered. In the Foundry a heat of cast iron was poured, efficient methods of molding were shown. Interest was manifest in the novel lighting system in use in this branch of the Shop Laboratories. In the Pattern Shop interest centered on the lathe work. Students were at work turning out souvenir pencil holders. In the old Armory building motion pictures of work in the Ford Automobile Factory were shown before a full house. All who visited the open house received souvenirs.

On October 21st. Mr. Hower of the Willys-Knight Motor Co. talked on the Knight motor. The talk was confined entirely to a description of the mechanical details of the sleeve-valve motor and the advantages which it had over poppet valve motors. These advantages Mr. Hower summarized as follows: No obstruction of parts by valves; no trouble from carbon formation on valves and valveseats; centralization of the expansive force of the gases on the piston; positive action, no springs being used; mechanical simplicity, there being no parts to get out of adjustment; and less 'wear and tear' than on the cam driven poppet valve type of motor. Mr. Hower illustrated these features with slides. The audience, which filled the seating capacity of the Engineering Lecture Room, was pleased with the lecture.

On November 4th Mr. Willman of the Studebaker Corporation talked on "The Relation Between the Manufacturing and the Sales Departments" of a company manufacturing specialties such as automobiles. He dwelt on the necessity for the manufacturing end of the business turning out a product which will please a reticent public, and on the necessity for the salesmen getting the prospective buyer's viewpoint before trying to sell him an article.

V. S. Day.

E. E. DEPARTMENT NOTES

The Electrical Engineering Society started its activities of the current University year with its "Annual Feed" on October 1st at the Electrical Engineering Laboratory. Eats, drinks and short talks constituted the program. President Gumm opened the meeting and introduced Professor Paine, who spoke of the spirit of cooperation between faculty and students and explained the intent and operation of the honor system in this department. I. W. Fisk spoke briefly of the relation of the Society to the work

of the department, and of the social and educational value of the Society. During the evening about eighty applications for membership were received.

On Wednesday evening, November 10, Mr. C. R. Underhill, Chief Electrical Engineer of the Acme Wire Company, spoke before a combined meeting of the Society and the Urbana Section, American Institute of Electrical Engineers, upon "Electromagnets". The lecture was well illustrated, and was a comprehensive treatment of the mechanical and electrical properties of electromagnets.

The beginning of the year has been marked by unusual activity in the literary work of the department faculty. At a recent meeting of the St. Louis Section, American Institute of Electrical Engineers, Professor Paine presented an illustrated paper upon "The Equipment and Work of the Engineering Experiment Station at the University of Illinois", Trygve D. Yensen presented the results of his recent investigations in a talk upon "The Magnetic Properties of Some Iron Alloys Melted in Vacuo". Professor Brooks spoke before the Illinois Municipal League upon "Modern Street Lighting and Its Relation to Automobile Headlights". He brought out the fact that cities should not require dimmers unless the streets are well illuminated, since to do so may increase the chance of accidents. The talk was illustrated by slides and demonstrations of various types of headlight dimmers and street lamps.

Among recently published articles by members of the faculty and Experiment Station staff are "The Design and Characteristics of Four Torsional Springs" by C. R. Moore, in a recent issue of The American Machinist, and "The Iron Cobalt Alloy Fe_2CO and Its Magnetic Properties" by Trygve D. Yensen, in the General Electric Review.

D. G. Evans.

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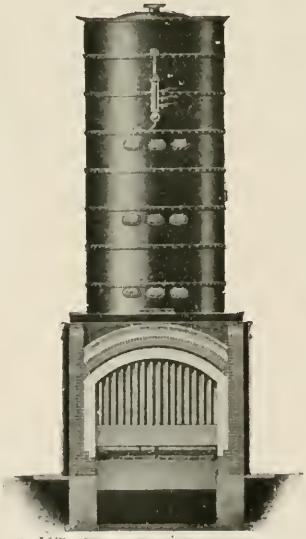

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VACUUM IRON

TRYGVE D. YENSEN

Engineering Experiment Station

In the minds of the uninitiated the term "Vacuum Iron" probably produces nothing more significant than a question mark. To those, however, who, like the writer, have been fortunate enough to have been associated with the development of this mysterious product, it conveys pictures of steep magnetization curves and narrow hysteresis loops. In their dreams they see these curves and loops, armed with staggering figures, conquering territory after territory in the field of electrical engineering; they see them occupying transformers, large and small, displacing old-fashioned silicon steel and throwing out superfluous copper; they see them revolving about the shafts of generators and motors, performing acrobatic stunts; they see them creeping into telegraph and telephone cables carrying human intelligence across the ocean as though it were but a pond; and finally—inorder not too tire the reader with too many visions—they see these conquerors revolutionizing the world generally. And after having performed all these feats they send back to their sovereigns millions upon millions of shining gold dollars.

What can be the diet that has caused such a dream?

About five years ago an ambitious idea started an investigation in the Electrical Engineering Department of the University of Illinois on the magnetic properties of iron and iron alloys. Only very faint notions prevailed, however, as to the proper method of attack, and no apparatus was available with which to carry on the investigation. Electrolytically refined iron had to be produced in order to have a reliable starting basis upon which to work. Crucibles had to be made, and, in order to stand the high temperature and the atmosphere of the electric furnace, these had to be made from fused magnesia. The fused magnesia was

not obtainable on the market, and so this also had to be made in the laboratory. Furthermore, this magnesia had to be made in a special furnace that had to be designed and built, an investigation in itself. An electric furnace in which to melt the iron was evidently also needed. Fortunately, Professor Parr was just then carrying on his Nickel-Chrome-Copper investigation in the basement of the Electrical Laboratory, and he very kindly consented to let us use his electric furnace, so that this problem was settled for the time being. The forging of the iron ingots that we expected to make was likewise solved without difficulty, as the Forge Shop had a power driven hammer that could be used for this purpose. Finally the problem of testing was attacked, involving electric, magnetic, mechanical, chemical, and metallurgical tests. With the assistance of the Departments of Chemistry, Physics and Theoretical and Applied Mechanics, preliminary arrangements for all of these tests were made; but it developed later that special apparatus had to be constructed in order to test some of the products properly.

After nearly a year of preparation we were finally ready to begin operations. The electrolytic iron had been produced, and small quantities of fused magnesia, made in the electric arc furnace, had been ground to powder and molded into crucibles. Everything in readiness, the iron was carefully placed in a crucible; this was in turn placed in a graphite crucible and securely covered, and the whole combination finally transferred to the electric furnace. After a few trial experiments to ascertain the best procedure, the iron was melted and solid ingots obtained. They were taken over to the Forge Shop and reverently heated up in a gas furnace and held under the power hammer. After a few blows, cracks began to develop and after a few more the whole ingot became a mass of cracks. The blacksmiths had been informed that these ingots were worth five dollars each, and they had been requested to exercise unusual care. The result of the attempt consequently brought down on the writer's head, already filled with consternation, the encouraging remark: "What sort of cast iron are you bringing us?" After trying for a month in vain to obtain forgeable ingots, it was discovered that the ingots would forge fairly well if heated only to a dull red heat. In other words, they were "hot short" but not "cold short." The writer's master's thesis being already overdue, this was taken advantage of, and a number of Boron alloys were prepared and forged into the desired shape for testing. A few days before Commencement the thesis was handed in and accepted, and thus ended Chapter I of the investigation.

Commencement over, plenty of time was available for the de-

termination of the cause of the first failure. After due deliberation and some experimenting it was decided that the atmosphere of the furnace instead of being reducing, as was supposed to be the case, was oxidizing, and that the electrolytic iron being very porous consequently was badly oxidized during the melting. The remedy then, was to introduce a reducing atmosphere, and this was done by burying the crucibles in crushed carbon. The experiment met with immediate success. The ingots forged beautifully at ordinary forging temperatures and a large number of test-bars of supposedly pure iron were made. Upon testing these, however, it was found that they were of rather poor and varying magnetic quality. Again consternation reigned for a time, until chemical analysis revealed the fact that the iron contained from 0.05 to 0.15 per cent carbon, evidently absorbed from the carbon monoxide atmosphere of the furnace. Furthermore, the electrical resistance test indicated that the iron had absorbed not the carbon alone, but the oxygen of the CO gas as well, so that but little had been gained by the new melting process. Just then the writer happened to read about the vacuum furnaces that had been successfully used in certain meatllurgical operations requiring very high temperatures. While the temperature needed for the melting of iron is moderate, (1530°C.), it occurred to him that a vacuum furnace would take care of all troubles caused by gases.

The new subject was investigated and it was found that the equipment would cost about six hundred dollars. With the treasury nearly empty the prospects for obtaining the coveted vacuum furnace were not very bright, and other methods were already being investigated, when something happened that unexpectedly solved the financial problem. The Director of the Experiment Station suddenly found himself without his administrative assistant, and in order to relieve the situation he asked the writer to fill the vacancy temporarily. It was six months before a new man was found, and in all that time the writer received his salary from the general Experiment Station fund and this money was saved to the Electrical Engineering Department. As soon as he returned to his own laboratory, work was commenced on the design of the vacuum furnace, and it was soon in process of construction. Before the year was gone the furnace was in full operation, turning out silver gray ingots shining like polished nickel. This was "Vacuum Iron."

Even without subsequent heat treatment this vacuum iron was found to be of very good magnetic quality, and the chemical and metallurgical analysis revealed a metal of unheard-of purity. (See Fig. 1.) The effect of annealing the test bars was then in-

vestigated. One of the bars was heated up to about 600°C. and after being slowly cooled it was tested magnetically. As was expected, the permeability had increased to some extent. The bar was then annealed at 700°C. and this time the permeability had increased very much. Annealing at 800 and 900°C. raised it still higher and it was thought that the limit had been reached, for the permeability now exceeded anything previously heard of. Annealing at 1000° and finally 1100° produced no marked change. It was then decided to anneal at decreasingly lower temperatures. This was done and the permeability increased to such values that we began to suspect our own apparatus, so much so that a new one was constructed according to the latest model

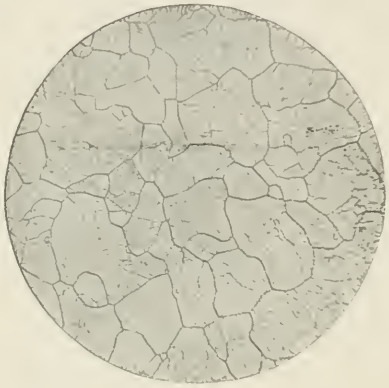


FIG. 1.

Photomicrograph of Pure Vacuum Iron Annealed at 1060°C. Magnified 40 Diameters

developed by the Bureau of Standards. (Mr. W. A. Gatward will deal with this in his paper in this issue on "Magnetic Testing"). Testing with the new apparatus revealed the fact that our previous figures, instead of being too high, were actually too low. To be on the safe side we sent the bar to the Bureau of Standards to be testeed, and to our delight the certificate showed that our last figures were correct. The maximum permeability that we had thus obtained was about 13,000, and this was an incentive to further investigation. More pure iron ingots were made and more bars prepared. By improved methods of annealing, the permeability climbed higher and higher until one rod set a record of 19,000, about twice the value for the best iron produced by previous investigators. The hysteresis loss was correspondingly low. Consolidating the conquered territory, the announcement of the result was made in the spring of 1914. But as with all un-

usual discoveries, very few comments were made. People naturally thought that something was wrong somewhere, and preferred to bide their time to see if more would come.

In the meantime the investigation proceeded and was next heard from in the spring of 1915, when the results of the effect of boron upon the iron was published. The announcement served chiefly as a reminder that the story was not finished and that greater things were yet to be told. At that time we already knew that some of our silicon alloys would make all previous results appear insignificant by comparison. The permeability curves had steadily grown steeper and the hysteresis loops had steadily grown narrower, threatening to disappear altogether; and as

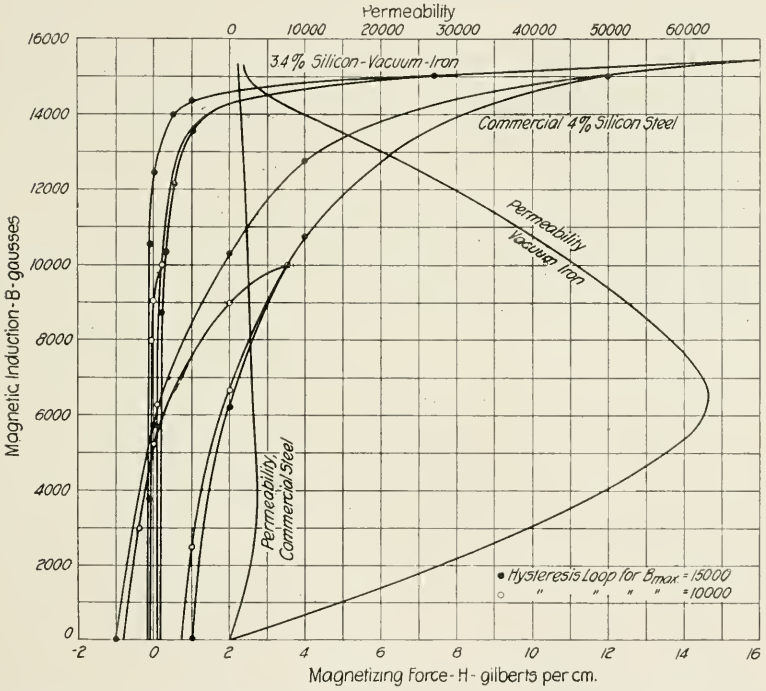


Figure 2—A comparison between vacuum iron and commercial steel, both containing between 3% and 4% Silicon, thoroughly annealed

spring approached the improvement continued in the same direction. By the time we were ready to write our report we had two alloys with permeability above 50,000, a large number whose permeabilities were above 30,000, and 32 alloys with permeabilities above 20,000. The hysteresis loop had narrowed down to such

an extent that the loss represented by some of them was only 1/10 of the loss of the best transformer silicon steel on the market. (See Fig. 2). The testing of these alloys presented some of the most difficult aspects of the investigation, as will become apparent from Mr. Gatward's article. But the work was finally completed and presented to the public in October, 1915. This time the writer had the support of others who had been given an opportunity of verifying the results in their own laboratories, and comments gratifying to the mind of the investigator were plentiful. Since the University decided to push the advertising, comments have been particularly numerous, and inquiries of all sorts are pouring in from the four corners of the earth. The writer could never have conceived of half of the purposes for which the world wishes to employ the vacuum iron or the vacuum process.

No wonder he has dreams.

Note—For detailed information regarding the vacuum alloys, the process of its production, and its properties, reference is made to the following sources:

Proceedings of the American Institute of Electrical Engineers, February and October numbers, 1915.

General Electric Review, September, 1915.

Bulletins of Engineering Experiment Station, University of Illinois, Nos. 72, 77, and 83.

MAGNETIC TESTING AND ITS APPLICATION TO IRON OF HIGH PERMEABILITY

W. A. GATWARD

Research Fellow in Eng. Exp. Station

It has been the author's privilege to work during the preceding year and a half with Mr. T. D. Yensen in connection with his research on the production of Vacuum Iron possessing extraordinary magnetic qualities. During the five years over which the research has so far extended there have been numerous difficulties which have at times seemed insurmountable and one of the most puzzling and also the most important problems has been in connection with the magnetic testing. It has been long recognized that wherever iron is used in connection with electricity, ordinary calculation at once becomes complicated because of the complex variation of the magnetic induction with the magnetizing force.

A glance at any magnetization curve will show that doubling the magnetizing force does not always cause a proportional change in the induction. As a matter of fact a slight change in the former may cause very great changes in the latter. It is evident from Fig. 1, Curve 1, that the steepness of the magnetization curve is the measure of the sensitiveness of the iron to changes in the induction. In the case of iron represented by a curve like Fig. 1, the sensitiveness is not nearly so great as in the case represented by Curve 2.

Right here lies the difficulty and up to the present time or rather until the recent production of the high permeability Vacuum Iron, this difficulty did not exist. For ordinary grades of commercial iron even of a permeability of 6000 to 8000, there never has been any trouble in determining the magnetic quality to a very satisfactory degree of accuracy.

As the quality of iron has gradually been increased it has become more evident that the old method of testing, which has been standardized for all commercial testing, was no longer accurate enough. It was at first thought that the trouble might be in the apparatus, but lately the results have been repeated in other laboratories, so there is no doubt that the very high sensitiveness of high permeability iron calls for either a change in the method of testing or a correction factor for the old method, viz., the double bar and yoke method.

There are two methods of magnetic testing that have always

been considered satisfactory; the one mentioned above, and the ring method. Both of these have been used to a great extent in connection with the testing of Mr. Yensen's Vacuum Iron, and the author is at present preparing a thesis upon the problem here discussed.

The ring method is very much the simpler and may be briefly described as follows: The sample of iron must be in the form of a closed ring and of course should be uniform both as to dimen-

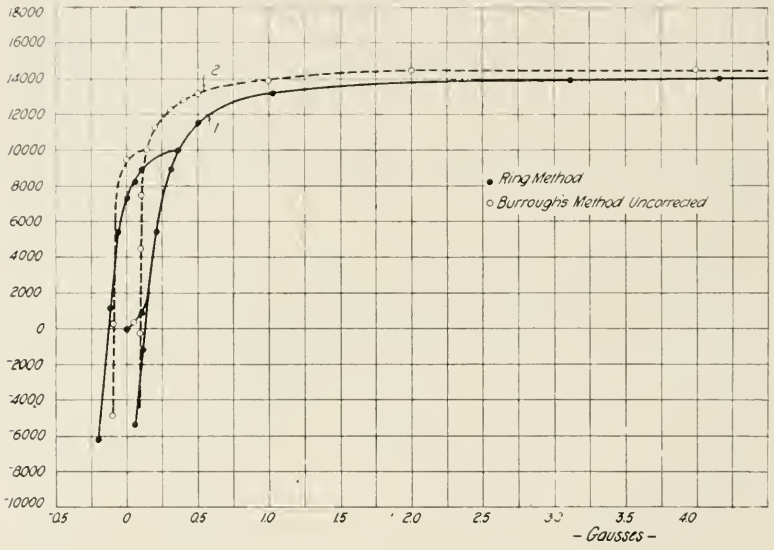


FIG. 1

Comparison of Magnetization and Hysteresis curves for same iron, tested by different methods

sions and quality. A secondary winding of enough turns to give a suitable deflection on the fluxmeter or galvanometer is wound uniformly over the iron. Next the primary winding is wound over the secondary and must be designed so that a fixed maximum current will saturate the iron to the desired degree. When the primary current is reversed there will be induced in the secondary a momentary E. M. F., and if the secondary is connected to a galvanometer, the needle will be deflected. In the present case a galvanometer proved unsatisfactory and a fluxmeter was used. This instrument is provided with a torsionless suspension and the de-

flections of the needle are independent of time and are directly proportional to the number of lines of force that cut across the secondary turns when the primary current is reversed. It is a simple matter to set the current at predetermined values and note the deflection of the fluxmeter when this current is reversed. The constants of the circuits and the dimensions of the iron are known and the calculations are comparatively simple.

From the above description it would seem that nothing more could be desired in methods of testing. This is far from the truth, however, for there are three objections to the above method.

First—The ring must be uniformly wound and there is no way of placing the wire except by very tedious hand winding. The reason this method has not become standard is probably because of the fact that for each test the windings must be put on by hand. There is not much difficulty in getting the windings uniform enough, so this can hardly be called an objection.

Second—On account of the ring form, the flux in the iron will not be uniformly distributed, but the lines of force will be more dense at the inside than at the outside. This effect varies with the ratio of the thickness of the ring to its diameter and the smaller this ratio, the less will be the nonuniformity of distribution. The result of this effect is that the average induction and hence the average permeability is determined and not the maximum which is desired. There is no way of knowing just how much the two will differ in any one case, but the average will always indicate a poorer iron than is actually being tested. The ratio of thickness to diameter can be decreased to a certain extent, but there are limits even to this. In the present research the rings have been 2 millimeters thick and the mean diameter has been 4 centimeters. It is believed that except for this second inherent error, the ring method is reliable for all qualities of iron. It may be that upon further investigation a correction factor can be determined or it may be found that none is needed. It is probable that the results for the higher values of permeability should be increased.

Third—The last objection is one that is not important since it can be overcome by making the ratio mentioned above small. The error is due to the fact that the primary winding is closer together at the inside than at the outside and hence the magnetizing force is not uniform. The calculations used in solving for the magnetizing force give the "H" that would exist at the center of a long solenoid. In ring form this must be increased by a factor that can be calculated from the constants of the ring. In

the case of the rings used this factor is 1.004, so it may be neglected without introducing serious errors.

The Burrows method is a substitute for the ring method just discussed and was devised for commercial testing especially because the samples of iron can be interchanged and also serve for specific resistance test bars. The procedure in testing is very similar to that for the ring method, but is much more complicated and tedious. The permeameter as constructed by the author follows the recommendations of the Bureau of Standards and the details are shown in Fig. 2. The essential features of the apparatus are two uniform solenoids of known constants placed six centimeters apart and parallel. The test bars should be practically the same but for ordinary iron this is not important. The two solenoids are supplied with independent currents and the magnetizing force can be controlled and measured. The ends of the rods are joined by means of two pairs of soft iron yokes which are made so they will not strain the rods when clamped in place. Over the main solenoids and near the ends are placed four compensating coils which are connected in series and whose purpose is to force the flux through the joint. There are three secondary coils of equal turns and they can be conveniently connected in opposition, with the fluxmeter in series. One of these test coils is placed at the center of the rod being tested, and this is the coil that is used in measuring the flux values. The other two are for balancing the flux, one being placed at the center of the other rod and the third being divided, one half at each end of the test rod. When the currents in the two solenoids and in the compensating coils are so adjusted that the flux threading these three test coils is the same, it is assumed that the flux is the same through all the iron path and that there are no consequent poles resulting from unequal flux or from leakage. The magnetizing force being known and the flux being measurable, the magnetization curve and the hysteresis loops can be determined. It is necessary to balance the flux for all points and this is very difficult, especially for points on the steep part of the hysteresis loops. There are numerous objections to this type of permeameter.

First—The effect of a strain due to clamping. The yokes are supposed to join the ends of the bars without straining them in any way. It is impossible to clamp the yokes in place and get uniform results with this method of testing and after experiencing much trouble, it was decided to place the yokes over the ends of the bars with no pressure at all. The holes in the yokes are as near parallel as it is possible to make them, but the bars may not be straight after annealing and even a slight pressure will

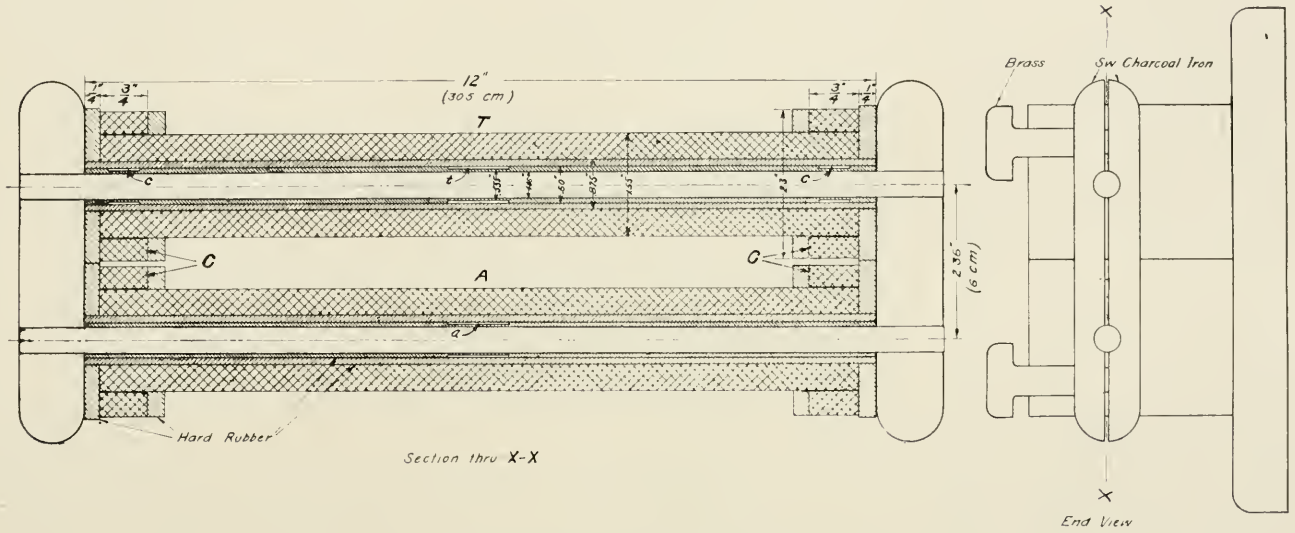


FIG. 2—PERMEAMETER—COIL DATA

T, *A* and *C* coils—10 layers No. 18 B. & S. enameled copper wi re, 20 turns per inch per layer (7,875 turns per cm.) *t* and *a* coils —64 turns each of No. 30 B. & S. d. s. c. copper wire.

C and *c* coils 32 turns each of No. 30 B. & S. d. s. c. copper wire—connected in series.

strain them enough to change the results entirely. This effect was not discovered until quite a number of rods were tested and these had to be restested. By using loose clamps it is possible to repeat a test at any time and check accurately.

Second—The effect of the compensating current. The compensating coils as stated above are for the purpose of forcing the flux through the joint at the yokes. For ordinary iron the reluctance of the joint is not very much greater than that of the iron and the compensating current will not be more than two times the current in the main coils under the worst conditions. The permeameter was designeed for testing low permeability iron and when so used the error introduced by the compensating current is negligible. However, when the iron is of very high permeability, the reluctance of the joint may be much greater than that of the rod and in the present investigation the current in the compensating coils was at times about 40 times that in the main coils. For points on the hysteresis loops it may even be higher, but that question has not been investigated. Theoretically, this error is not very important but under actual test it has been found that the maximum correction is 17%. In other words, due to the effect of the compensating current, the apparent value of H must be increased 17% at the steepest part of the magnetization curve. This correction is directly proportional to the quality of the iron and, neglecting the correction, leads to excessive values for permeability. It seems probable that even the correction of 17% is not sufficient to bring the curves to their proper values, but it is not possible at the present time to say just how much the values should be reduced.

Third—The last objection to the Burrows method is, that for Vacuum Iron testing the operator much have experience in the use of the method and must make a study of each case and must exercise care and judgment in determining values, especially at the sensitive points of the curves. It has only been recently that retests have checked the original data and the work must be carefully done to make this possible.

With this much discussion of the two methods of testing a few conclusions can now be presented based on a comparative study of results from each method. In Fig. 1 are given two hysteresis loops and two magnetization curves. The curve numbered (1) was plotted from data taken with the ring method and number (2) from uncorrected data from the Burrows method. It can be seen that there is a decided difference in shape and in maximum values. There is always an uncertainty as to the actual quality of the samples, and it may be that the iron in the differ-

ent forms is not the same. However, in the present case they are as near the same as can be attained and numerous tests indicate that there is very little deception, if any, due to difference in quality. Applying the corrections that we know should be applied from the discussion of the two methods will bring the two curves into closer agreement and somewhere between the two lies the true curve.

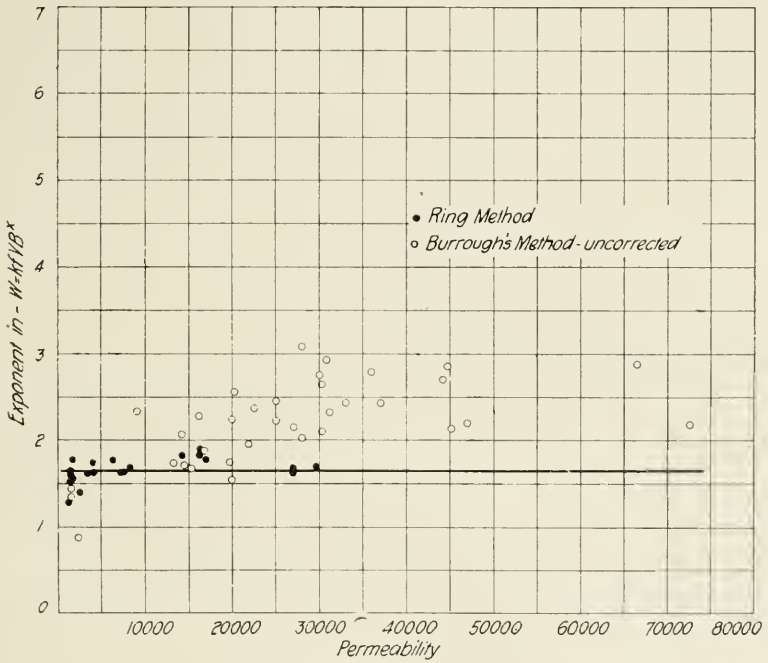


FIG. 3

Average values of Steinmetz exponent as determined by ring method

There are many indications that of the two methods, the ring method will give results that are nearer the correct values than the Burrows method. Judging from consistency, the ring method is entirely satisfactory, as will be seen from a study of Fig. 3. The horizontal lines represent the exponent in the equation $W = k.f.v.B^x$, (x) having been determined to be approximately 1.6 by Steinmetz in 1892. This line is drawn through the means of the points obtained by the ring method. The other points were obtained by the Burrows method. Without considering the actual value of the constant (x), the consistency of the ring

method and the inconsistency of the bar and yoke method are at once apparent.

Another way of bringing out a comparison is as follows: It seems self-evident that the higher the permeability, the better the iron and the lower should be the loss due to hysteresis. This is shown graphically in Fig. 4, in which the loss in ergs per cu. cm. per cycle are plotted against the maximum permeability. The curve is again drawn through the points determined by the ring method and the points show remarkable consistency. The loss as determined by the bar method is at times greater for rods of higher permeability. This curve brings out another important point, viz., that for iron of very high permeability, there is a very slight decrease in hysteretic loss with increase in permeability.

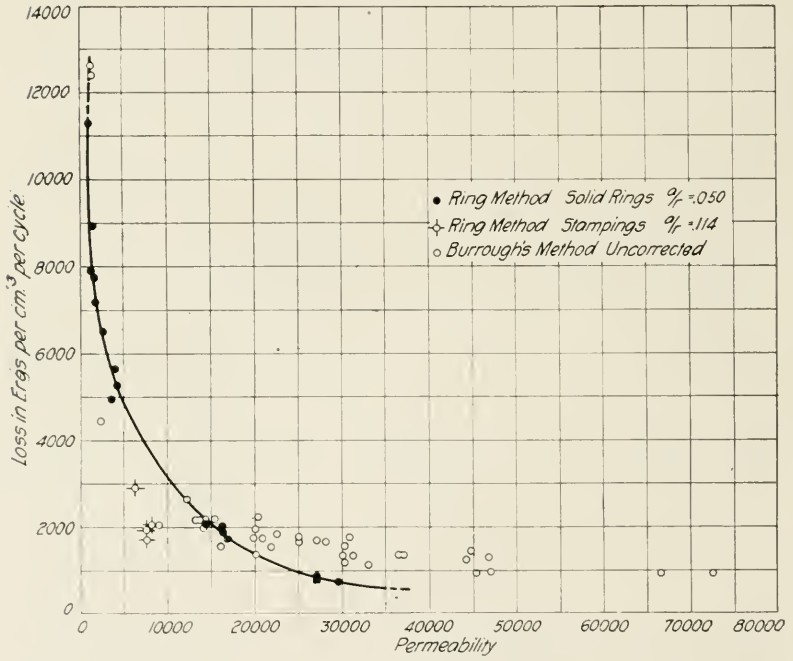


FIG. 4

Curve showing consistency of ring method

The points designated by η introduce another question mentioned in the discussion of the ring method of testing. The dimensions of these rings are different from those of the rings through which the curve is drawn, and they are built up from stampings rolled from a very high grade of Vacuum iron. As stated before the permeability determined by the ring method is

the average permeability, and this may vary from the maximum by an unknown amount. The ratio of the maximum to the average can be kept low by making the ratio of ring thickness to ring diameter, low. The dimensions of the solid rings are: T, 2 cm. and D, 4 cm. The dimensions for the stampings are: T, .407 and D, 2.56 cm. Hence the ratio of T/D is greater for the stampings. We should expect the permeability as determined by the ring method to be low for both sizes of rings, but the discrepancy would be greater for the stampings than for the solid rings. It is hoped that further investigation will result in definite conclusions as to the amount the values should be increased in the ring method and how much they should be decreased in the bar method. Judging from the conditions represented in Fig. 4, the amount by which the curve should be corrected is less than the amount the points for the stampings should be corrected, but there have not been enough tests made to warrant a definite statement in this connection.

In conclusion, the fact must be emphasized, that magnetic testing when Vacuum Iron is involved is entirely different from magnetic testing as most people understand it, and there is no problem demanding greater care or presenting greater difficulties.

In regard to the two methods discussed above, it can only be said that the results determined by both of them are evidently in error and that the correct values lie somewhere between the two extremes. It must be remembered that the only parts of the curves affected by these errors are those where the iron is very sensitive, that is, where the curves are steep, or show great changes in magnetic induction for very light changes in magnetizing force.

NOTES ON ELECTRICALLY DRIVEN DEEP WELL PUMPS

I. W. FISK AND P. S. BIEGLER

Electrical Engineering Dept.

Where large quantities of water are required from deep well supplies it is generally the case that one well is not sufficient and more often that many wells are necessary. The location of these wells, relatively to each other, depends upon many conditions such as the amount of water available at the water bearing strata, the velocity of water flow to the pump barrels, the amounnt of sand present, etc. Thus deep wells are very often scatterd over a large area and the question of the proper method of power supply to the pumps is more or less of a problem the solution of which may depend upon local conditions.

For very large wells the power might be supplied by compound or triple expansion steam engines, while, for smaller installations, either the steam head or the electrically driven pump is more suitable. The first of these possibilities, however, will not be considered further in this paper.

For widely distributed wells the steam driven pump has some advantages, but many serious disadvantages, as outlined below.

Advantages:

1. Simplicity.
2. Small floor space required.

Disadvantages:

1. High cost of steam transmission system.
2. High radiation losses.
3. Rapid deterioration of heat insulation.
4. Pump rods not accessible.

The electric motor driven pump has proven most satisfactory for many such installations and has the following advantages and disadvantages.

Advantages:

1. Simplicity of operation.
2. High efficiency.
3. Cheap construction for power transmission.
4. Control from main station.
5. Allows easy access to pump rods.

Disadvantages:

1. High first cost of motor and pump head.
2. Increased amount of floor space required.

From the above summary it appears that the electrically driven pump, for small wells at least, has the preference over a steam

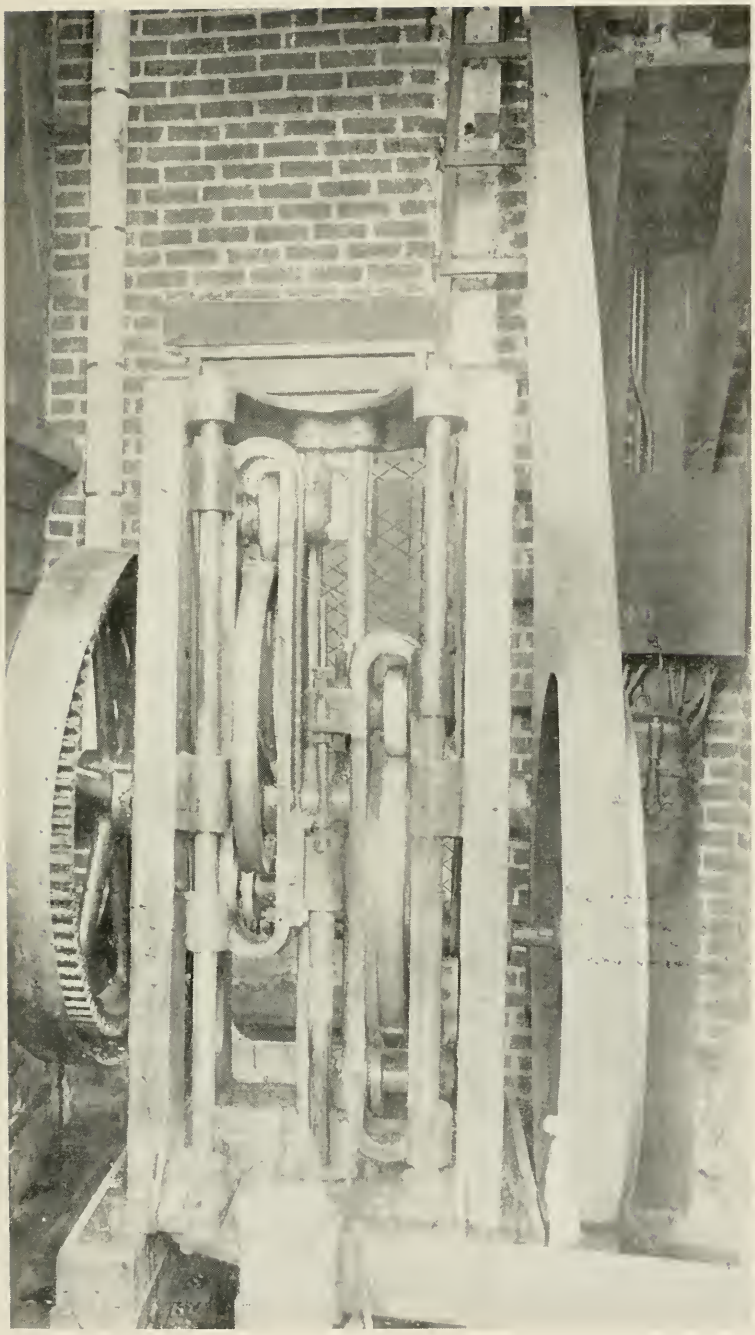


FIG. 1.

head, and the advantage becomes greater as the distance between wells increases.

Fig. 1 shows a method of economizing in floor space when electric driven is used.

To make a complete comparison between these two methods of pumping, for any specific conditions, would involve an exhaustive study, and such a comparison is beyond the scope of this article.

The authors have had occasion to test an installation consisting of electrically driven deep well pumps and have also determined the actual cost of pumping water under practical conditions of operation.

Upon attempting to take readings with ordinary indicating wattmeters, ammeters annd voltmeters it was found that the current and power fluctuate so rapidly and widely during a pump stroke that it was impossible to make even a good guess at the average instrument readings. This undoubtedly has been the cause of many mistakes in the choice of size of motor, resulting in oversized driving units. However, with an integrating wattmeter, which gives total energy delivered during a given time, one may find accurately the average power required by the pump motor.

In discussing electric drive for pumping purposes attention should be called to the importance of choosing such sizes of motors that each may be operated, as nearly as possible, at its full load rating, especially when supplied from alternating current lines. If the motors are only lightly loaded the power factor of the motor load will be very low. This is exceedingly important when the pumping company operates its own electric power plant, for low power factor means poor efficiency throughout the electrical system and also higher investment and fixed charges. When power in large amounts is purchased from central stations, moreover, the rates should be materially lower for loads of high power factor than for low power factor loads.

Today the necessity of choosing motors of proper size for this service, the assumption is made that the average power supplied to a pump motor is to be 5.41 H. P., or 4.08 K. W., which was actually found to be the average power required by a large number of wells driven by 10 H. P. motors. From Fig. 2 it is seen that, at this intake of a 10 H. P. motor, the efficiency is 85.5%, the P. F. is 64.2% and the output is 4.68 H. P. If this load is drawn from a 5 H. P. motor, then we see that the efficiency is 84.1%, which means an intake of 5.57 H. P. or 4.16 K. W., as shown by curves in Fig. 4.

The 5 H. P. motor, therefore, is better adapted to this load for the following reasons:

1. P. F. increased 13.6%.
2. Less expensive and more efficient generating equipment, due to higher P. F.
3. Less investment in motors.

While the 5 H. P. motor is 1.4% less efficient than the 10 H. P. motor, under these conditions, this loss of efficiency is insignificant.

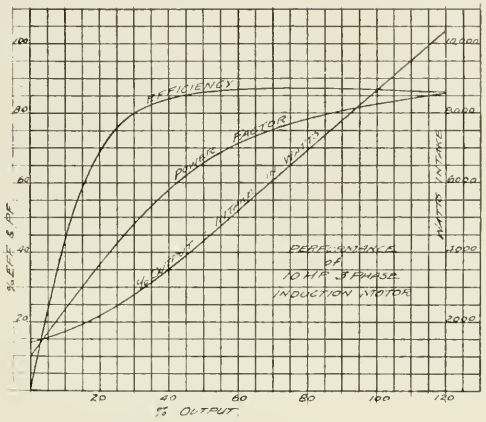


FIG. 2.

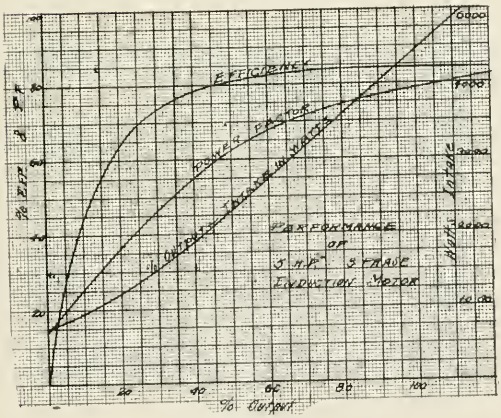


FIG. 4.

In order to determine the actual cost of pumping water it is necessary to know the operating expense and the detailed investment. In the case of the installation under discussion the operating expense is almost entirely made up of the cost of generating electric power, since the power house attendants operate and repair the pumping machinery with very small expenditure of time. The cost of waste, oil and repairs at the pump houses is very small and is here lumped in the item "maintenance" which has been found to be close to 2% of the total investment. With these items provided for the only remaining operating expense is the cost of electric power.

Having obtained the total investment in the pump house and well, one may readily apply interest, insurance and tax rates, according to conditions in the locality. Regarding depreciation, however, it is more of a task to decide upon the probable life or usefulness of each item of the equipment; but, for present purposes, the authors have assumed an average life for the complete well and pumping unit. The amount to be set aside for a sinking fund to cover this depreciation is then determined from the mathematical equation for sinking funds.

A detailed analysis of the cost of pumping water for an average well, of those tested, is given below:

Investment:

Cost of driving 160 ft. well	$ 400
Well equipment	548
Pump head	650
Building and setting of machinery	158
Motor and electric equipment	178
Piping to reservoir	86
Labor installing machinery	200
Total cost	$2220

Fixed charges:

Assuming the average life of this equipment to be 25 years the amount that must be put into a sinking fund each year, to cover depreciation, is given by the formula:

$$S = \frac{Ar}{R^n - 1}$$

where S = sum set aside annually.
A = cost of reproduction, or investment.
r = interest on one dollar for one year.
R = $1 \times r$.
n = life of equipment in years.

The value of "S" in this case is $46.60.

Then the total fixed charges are found as follows:

Depreciation	$ 46.60
Interest at 5%	111.00
Interest and taxes at 1%	22.20
Maintenance at 2%	44.40
Total fixed charges	$224.20

Performance of pumping unit:

From readings taken on 17 pumps the operating conditions are shown as follows:

Average power intake of motor	4.08 K.W.
Average speed of pump	27.4 R.P.M.
Average water displacement per rev.	928 cubic in.
Average head on pumps	100 ft.

Assuming that the pumps deliver 90% of the theoretical pumpage, it is seen that each pump delivers

$$\frac{928}{1728} \times 7.47 \times 27.4 = 110 \text{ gal. per min.}$$

$110 \times 8.33 \times 100 = 91{,}700$ ft. lbs. per min. delivered. by the pump or

$$\frac{91{,}700}{33{,}000} = 2.78 \text{ water H. P.}$$

It is of interest to note that the over-all efficiency of the motor driven pump is

$$\frac{2.78}{5.47} = 50.8\%$$

Total cost of pumping water:

If the quantity of water pumped per year and the electrical energy thus required are known, it is possible to get at the operating expense for any cost of electrical energy. Since the electrical energy for pumping is very commonly purchased, the total cost of pumping 1000 gallons of water against a 100 ft. head has been found for various electrical energy rates.

Average quantity of water pumped per year:
$110 \times 60 \times 24 \times 365 = 57{,}800$ M gallons.
Electrical energy required per year:
$4.08 \times 24 \times 365 = 35{,}800$ K.W.H.
K.W.H. required per M gallons:

$$\frac{35{,}800}{57{,}800} = .619$$

Total fixed charges per M gallons:

$$\frac{22420}{57800} = .388 \text{ cents.}$$

Cost of pumping 1000 *gallons against* 100 *ft. head:*

Ratio per K.W.H. cents.	Cost electrical energy—cents.	Fixed charges cents.	Total cost.
1	.619	.388	1.007
2	1.238	.388	1.626
3	1.857	.388	2.245
4	2.476	.388	2.864
5	3.095	.388	3.483

It should be borne in mind that this is only the cost of raising the water from the bottom of the well to the surface reservoir, and does not include any overhead expense.

Conclusions:

1. High power factor is essential to the efficient operation of the electrical system.

2. It is exceedingly important to choose motors of such size and characteristics that they may be operated at high power factor and efficiency.

3. Water pumping companies using electric drive should find out, by actual test, whether motors are being operated at proper load.

4. Where purchased power is used care should be taken to insure high power factor in order to get electrical energy at minimum cost.

INVESTIGATION OF DIRECT CURRENT CORONA AS CARRIED OUT AT THE UNIVERSITY OF ILLINOIS

J. W. DAVIS AND C. S. BREESE

During the last three years the Electrical Engineering Department of the University of Illinois have been carrying on investigations having to do with the phenomena accompanying the production of high dielectric stresses in air. Potential differences ranging from 500 to 20,000 volts are used to produce these dielectric stresses. Both parallel wires, and wires and cylinders concentrically arranged have been used as the boundaries of the electric fields set up in the dielectric by these potential differences. It shall be the purpose of this paper to give a more or less popular description of the general phenomena thus far observed at the University of Illinois, together with a description of the equipment used in connection with the investigations.

It is widely known that dry air is one of the best of the electrical insulators known to science. As a true insulator the current leakage through it is directly proportional to the potential difference maintained across it and to its cross section, and inversely proportional to the length of the path the current takes. However, if the potential difference across this air dielectric is gradually increased a critical point is finally reached where the current increases per unit increase of potential difference is enormously greater than at the previous potential differences. The value of this critical voltage is well below that of the "spark-over voltage" in most cases, and similarly to the latter, depends upon the size and spacing of the wires, their surfaces, and the character of the dielectric between them. If the potential difference is further increased the discharge becomes visible, a bluish light being emitted from the dielectric immediately surrounding the wire. This visible discharge, and in fact all discharges at potential differences between the above mentioned critical voltage and the spark-over voltage, are known as "Corona" discharges.

Theory of Corona Formation

The modern theory of the conduction of electricity through gases (the dielectric—air—is the gas in this instance) states that when a potential difference is placed across a gas, many of the molecules of the gas break up into smaller, electrically charged particles called ions, some of these particles being positively and some negatively charged; and that these ions act as carriers, transporting the electricity through the gas from one charged surface

to the other. Under these conditions the gas is rendered at least partially conducting and is said to be ionized.

As the potential difference across the dielectric is increased the numbers and velocities of the ions increase, with a consequent increase of current density in the dielectric. Finally, however, as the potential difference is increased the velocities of the ions become great enough to form other ions by impact with the molecules of the dielectric. This phenomenon is known as ionization by collision. Obviously at this stage the number of ions suddenly increases very rapidly, the current increase per unit increase of potential difference being correspondingly large. This marks the beginning of the corona stage.

It so happens that the ion velocity necessary to produce new ions by collision is very nearly equal to the velocity necessary to produce light, so that a faint bluish glow along the wires either accompanies or immediately follows the production of corona.

Commercial Importance of Corona

The phenomena of corona can be of importance to the commercial world only when the maximum value of the operating potential equals or exceeds the critical voltage at which corona losses start. In America the potentials used in the transmission of power by direct current have not become great enough to produce appreciable corona losses. However, the alternating current transmission line operating potentials used are much higher than the direct current potentials and many times the corona power loss on long lines becomes appreciable. Also the corona leakage through bushings, line insulators and machine windings may cause excessive heating in these parts of the circuit. Ozone is produced when air forms a part of the dielectric in which corona occurs and as ozone is a very strong oxidizing agent it causes a rapid deterioration of most insulating compounds. Rubber compounds are especially susceptible to these deteriorating effects.

For these reasons one of the most important considerations in the design of extremely high voltage apparatus is the consideration of the effects of corona leakage currents, both as to loss of power, and as to destructive qualities.

Previous Investigations

The phenomena connected with alternating current corona have been investigated by Steinmetz, Ryan, Peek, Whitehead and others and formulas have been developed for the starting voltage in aid for the different sizes of wire and at various gas-pressures. However, but little work of importance has been done on direct current corona, Watson and Shaffers (Europe) being the most important workers in this field.

Investigations of the University of Illinois

The corona investigations at the University of Illinois have been confined entirely to the study of the corona characteristics as found when continuous potentials are applied between small wires and cylindrical tubes, the wires being strung axially along the tubes. The investigation apparatus took these forms for the following reasons: firstly—it has been found that the form and intensity of the corona discharge when the wire is connected to the positive side of the line differs very materially from the discharge when the wire is connected to the negative side of the line. These two conditions can be studied separately and independently only when direct current potentials are used; and secondly—the wire-cylinder form of apparatus is used because the field distribution between the wire and the tube is extremely simple and symmetrical as compared to the distribution obtained between two parallel lines.

It is hoped that with the simplified apparatus now in use the laws governing the so-called "positive" (wire positive; tube negative) and "negative" (wire negative; tube positive) corona may be ascertained and the corresponding formulas developed. It is believed that the laws governing the alternating current corona discharges can be determined from the two dissimilar direct current discharge formulas.

Details of Experimental Apparatus

The plant used for the production of high potential direct currents consists of forty, 500 volt, 250 watt, shunt generators. The machines are divided into three sets, one of twenty machines and two of ten machines each as shown by Fig. 1.* Each set is driven by a shunt motor. The armatures of the machines are permanently connected in series, and the field of each machine is connected across its armature as shown in the diagram of connections, Fig. 2. A knife switch is included in each field circuit so that any machine may be excited or allowed to run idle as desired.

The frames of the machines are thoroughly insulated from the ground and the shafts are connected together through flexible insulating couplings. In the newest part of the installation one side of the armature of each machine is connected to the frame of the machine. In this manner the greater part of the dielectric strain is put on the insulation external to the machine and the strain be-

*Fig. 1 shows only two sets of machines. The third set was installed this fall after the photograph was made. (See Frontispiece.)

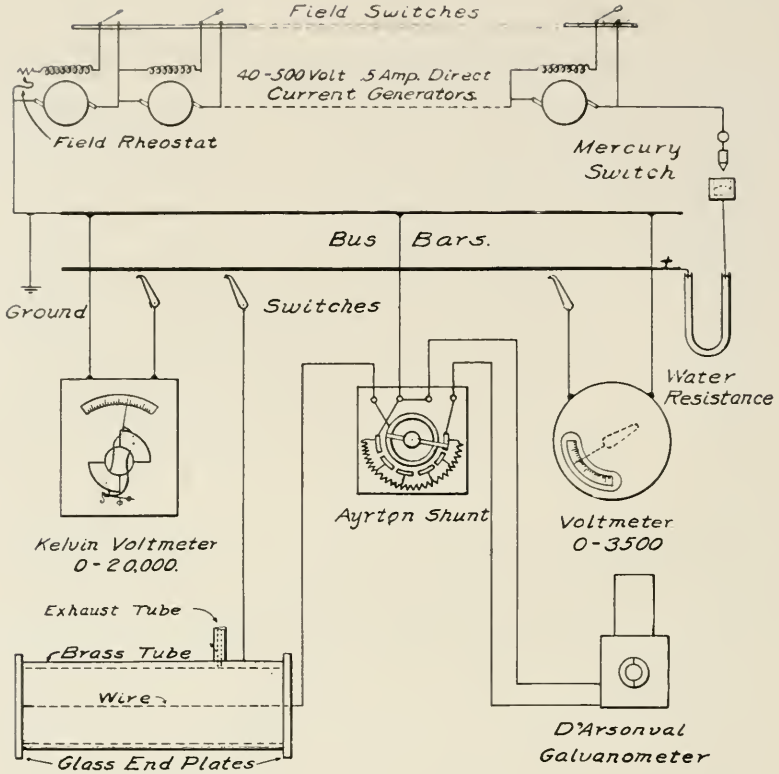
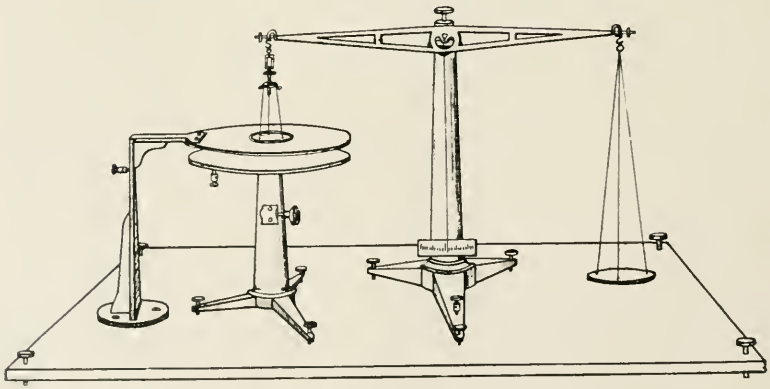


DIAGRAM OF CONNECTIONS.
FIG. 2.



ATTRACTED DISC ELECTROMETER.
FIG. 3.

tween the armature winding and the frame is definitely limited to the potential generated in the one machine.

The line potential can be adjusted to give any desired value up to 20,000 volts as a maximum by (a) closing the desired number of field switches, (b) varying the speed of any of the sets, and (c) by changing the resistance in the field of the generator connected to the grounded side of the line. The voltage is measured by means of two electrostatic voltmeters, one of the Kelvin type for measuring the higher values of potential used, and the other of the Braun type for measuring the lower values (below 3500 volts). These voltmeters are calibrated from time to time by means of an attracted-disc electrometer.

The electrometer is shown in Fig. 3, and is operated as follows: Connect the two points whose potential difference is desired to the two plates, the point of higher potential to the lower plate and the point of lower potential to the upper plate (guard ring). Also connect the point of lower potential to the suspended disc. The connection to the disc is made through the frame of the balance. An electric field between the upper plate and the lower plate will have been established upon the completion of the connections. The intensity of this field will depend upon the distance between the plates and the difference of potential of the two points, and the force of attraction between the plates is directly proporional to the intensity. That portion of the total force which is exerted on the disc is measured by means of the balance.

Knowing the dimensions of the plates, the distance between the plates and the force, the difference of potential may be calculated by the formula*

$$V = D\sqrt{\frac{8\,\pi\,g\,W}{A}}$$

where V = potential difference.
D = distance between plates.
W = weight on balance in grams.
A = effective area of disc.
g = acceleration due to gravity.

The function of the guard ring is to produce a uniform electrostatic field between the suspended disc and the lower plate. However, there is still a considerable spreading of the electrostatic lines of force at the outside edge of the disc and it is practically impossible to obtain absolutely accurate determinations of the difference of potential corresponding to a given force. Determina-

*A discussion of the suspended disc electrometer is given in Vol. 2 of Maxwell's "Electricity and Magnetism."

tions that are accurate to within one-half of one per cent are obtainable, however, if the distance between the plates is made short. Under these conditions the spreading of the lines of force is very small, and the effects of the boundary conditions (at the outside edge of the guard ring) also become negligible.

The corona current which flows between the wire and the brass tube is measured by means of a D'Arsonval galvanometer and Ayrton shunt. The galvanometer, shunt and tube are connected in series.

The figure of merit of the galvanometer is determined from time to time, an accurate resistance of high value and a calibrated dry cell being used in making the determinations. The cell is calibrated by means of a laboratory-standard voltmeter.

The complete connection diagram is given in Fig. 2. One terminal of the generating plant is grounded. The other terminal is connected to the high-tension bus through a high resistance consisting of a glass tube filled with distilled water, and a mercury disconnecting switch. The resistance is for protective purposes only. Its function is to limit the current in case the voltage suddenly becomes excessively high and produces an arc between the wire and the tube, or in case of accidental short circuit.

RESULTS OF INVESTIGATION.

Corona investigations at the University of Illinois have been made by Farwell, Owens and Faulkner, and are now being continued by Messrs. Crooker and Warner and the authors of this paper, under the direction of Dr. Jakob Kunz and Profesor E. B. Paine.

Farwell not only was the first man at the University of Illinois, but also he was one of the first, if not the first man in America to make a systematic study of the phenomena of direct current corona; and the knowledge of this field of research today is largely due to his work.

The characteristics of the conoa discharge seem to depend entirely upon the nature of the potential applied, the character and condition of the dielectric, and the spacing and physical properties of the conductors. The general results of the investigations of corona in air follow:

When corona is formed by applying continuous potentials to parallel wires the positive discharge (discharge at the positive wire) takes the form of a thin layer of bluish light immediately surrounding the wire. The negative discharge assumes the form of bright spots called "beads." These beads are more or less uniformly distributed along the surface of the wire. When alternating potentials are applied the wires change polarity continually

and the resulting discharge is a combination of the uniform positive glow and the beaded negative glow.

When continuous potentials are applied to the wire—tube form of apparatus shown in Fig. 2, the corona phenomena are very similar to those observed with the parallel wires. With the wire positive and the tube negative the wire is surrounded by a thin layer of bluish light. No visible discharge occurs near the tube surface. As the voltage is increased the dielectric ionization, the electron velocities and the current density increase, the discharge becomes more brilliant and finally if the voltage is increased sufficiently an arc forms. The positive end of the arc generally is not hot enough to burn the wire in two. With the wire negative the first indication of the failure of the air as an insulator is an unstable glow surrounding the wire. As the potential is increased the character of the discharge changes, the current becomes steady and beads form at more or less regular intervals along the wire. If the current is increased above certain limits the discharge character again changes and an arc is formed. The negative end of this arc is very hot and the wire is almost sure to be burned off unless the circuit be broken immediately after passing to thhis stage of the discharge.

The general apearance of these discharges is not changed by a decrease in dielectric (air) pressure until a pressure lower than ten millimeters of mercury is reached. As the pressure is decreased (below atmospheric, but above ten millimeters pressure) the voltage necessary to maintain a given value of current decreases, and simultaneously the brilliancy of the beads which make up the discharge surrounding the negative wire is increased.

The relation between the critical (corona starting) voltage and wire diameter for different sizes of wire has been detremined, both for positive and negative discharges. In general the critical electrical intensity—the volts per centimeter at the surface of the wire which are necessary to start the corona discharge—differs for the two cases. For small sizes of wire the negative glow appears at lower potentials than the positive, while for larger sizes the reverse is true. With air at atmospheric pressure as the dielectric, Farwell found the critical diameter—diameter at which the critical voltages for the wire positive and the wire negative are equal—to be 0.075 millimeter.

The effect of temperature on the magnitude of the corona discharge has been determined by Farwell for temperatures varying from 15 deg. to 25 deg. centigrade. He found that for an increase in temperature, the current corresponding to a given voltage increased in value, and that a greater increase occurred when the wire was negative than when positive.

Moisture in the air decreases the magnitude of the discharge for a given potential difference. With the wire positive and the tube negative a five per cent decrease of current was obtained with a change in dielectric humidity of 68.5 per cent; and under similar dielectric conditions with the wire negative the current decreases at constant potential was ten per cent. Steel, iron, copper and nickel wires have been tested to determine the effect of material upon the character and magnitude of the discharge. No great differences in the characteristics were observed. An attempt has been made to deflect the corona discharge by means of strong magnetic fields. No effect upon the appearance or magnitude of the discharge has been detected. A sudden increase in the pressure of the dielectric has been observed at the instant the corona discharge appears. Farwell found the magnitude of this pressure increase to be of the order of one centimeter of mercury at atmospheric pressure. Continuing this discovery Mr. Warner is attempting to determine the relationship between this ionization pressure and the corona current.

The corona characteristics are again changed if a small arc is placed in series with the tube. With the wire positive the characteristically uniform bluish glow changes upon the introduction of the arc to a larger and more brilliant purple glow whose boundaries are ragged; with the wire negative the discharge changes from the discontinuous beady corona to a more or less uniform continuous corona containing bright spots at intervals along the wire. The introduction of the arc into the circuit superimposes a high frequency current and it is this high frequency current that produces the radical change in the characteristics.

Summary and Conclusions.

The relations between the corona voltage and the size of the wire, between the corona current and voltage for different sizes of wire, different pressures, and different humidities and temperatures, were investigated by Farwell. Throughout these investgations air was used as the dielectric.

Owens continued the investigation of corona in air by studying the electric field distribution between a wire and cylindrical tube, the wire being strung axially inside the tube. He found that for the corona stage, under almost all conditions of pressure, voltage and current investigated, the field in the tube departed widely from the true electrostatic field. It was not possible to obtain very accurate data in the immediate vicinity of the wire but the deviation from the electrostatic field at this point was much less than in the other parts of the field. The dis-

tortion of the field is probably due entirely to the superposition of another electric field, this latter field having its origin in the ions of the dielectric.

Faulkner investigated the character of the corona discharge around a wire passing through a circular opening in a metal disc. His work included experiments both with the wire positive and negative, wtih respect to the disc. In general, the characteristics of the positive and negative discharges were the same as those obtained by Farwell with his wire-tube form of apparatus.

Mr. Warner in addition to continuing Farwell's investigation of the phenomena of ionization pressure for air is attempting to determine the relation between ionization pressure and current density for pure gases. For air, hydrogen and nitrogen he has found the relation to be linear. At present carbon dioxide is being used as the diaelectric.

Mr. Crooker is investigating the effect of conductor surface upon the corona characteristics with a dry aid dielectric. Steel, iron, nickel and copper wires with various surface conditions have been used. For wires having half of their lengths polished, and the other halves coroded, he found that the characteristics of the discharges from the dis-similar halves were a function of the voltage and pressure; and that in general, for any given voltage the discharges were dis-similar in appearance, magniture and stability.

Owens' investigation is of special importance since it exposes at least one of the fallacies of all theories of corona thus far proposed, namely, the assumption that the electric intensity at the surface of the wire is the same as that produced by the electrostatic field. No theory has yet taken into consideration the field produced by the free ions in the tube.

One great difficulty that must be overcome if a consistent theory for the formation of corona in air is to be developed is that of maintaining a dielectric of constant chemical composition and physical characteristics. In the first place air is a mixture of various gases and its composition may vary slightly from day to day, or week to week, on this account. Secondly, large quantities of ozone are formed immeditely upon reaching the corona stage and the characteristics of the gas mixture are changed. These changes in composition and state have a very marked effect on the characteristics of the corona discharge. In order to overcome these difficulties investigations are now being made by the authors of this paper in which pure gases are used as the dielectrics.

Only those gases whose compositions and characteristics are not known to be affected by electrical discharges (in other ways than by ionization) will be used. Hydrogen is being used as the dielectric at the present time. The phenomena thus far observed with this gas are in general similar to those obtained with air as the dielectric.

MODERN STREET LIGHTING.

MORGAN BROOKS

Professor of Electrical Engineering

The lighting of streets has long been recognized as a necessity of community life, altho requiring large expenditure. Early street lighting was by means of feeble lanterns carried by night watchmen patrolling the streets; candles and oil lamps enclosed in fixed lanterns of more or less ornamental design were also in use centuries ago. Glass was seldom used, the light being allowed to flicker thru perforations in the sheet metal of the lantern. Illumination was not expected; these early lamps served chiefly as markers to indicate the direction of the street.

Relatively brilliant illuminating gas was produced toward the close of the eighteenth century,—a steam automobile lighted with gas lamps surprising the inhabitants of Redruth, Cornwall, as early as the year 1792,—but not till the opening of the nineteenth century was gas conveyed in underground pipes used for the lighting of streets. The electric arc lamp, discovered by Davy at this time in 1808, would undoubtedly have become a strong competitor but for the want of an electric generator. It is nearly seventy years before we find the Paris boulevards brilliantly illuminated by the "electric candle" arcs operated by the first commercial alternator. Direct curent arcs quickly followed and spread with great rapidity, almost monopolizing the lighting of important thorofares in all large cities, altho on account of expense they did not displace gas and oil on less important streets.

The demand for a less powerful unit than the electric arc brought the carbon incandescent lamp, but owing to inefficiency as compared with improved gas and oil burners they have not been extensively used in street lighting. The recent development of the metal filament, especially in the present gas-filled type of tungsten lamps, which for a given energy furnish five times the light of the best carbon lamps, has stimulated electric

street illumination greatly. Tungsten lamps have not only largely superseded gas and oil lamps, but have driven out arc lamps almost completely, owing to their superior color, steadiness and adaptability to every need. Where gas lighting remains it is sometimes because gas companies have made attractive rates in an effort to retain a vanishing business, and partly because of the first cost of installing a new system.

The absolute quantity of light required for acceptable street illumination is less than is commonly supposed, provided the distribution is fairly uniform. The eye has wonderful power of adaptation to dim illumination, as evidenced by its ability to see quite well by moonlight, which is scarcely more than one millionth of sunlight. Where there are deep shadows, however, moon-light is insufficient, since with dim illumination extreme diffusion of light is necessary. The atmosphere diffuses sunlight to such an extent that the diffused light of the sun reflected from dust particles is ample for purposes of vision, while direct sunlight already surfeited with light. The atmosphere must also diffuse though much stronger does not increase the response of the eye moonlight, but the reflected moonlight is too faint to be recognized in vision. The use of powerful lamps at long intervals is always unsatisfactory, since the eye in passing rapidly from strong illumination near a lamp to the dimly lighted roadway beyond cannot see immediately owing to sluggish recovery from strain. Where fine details and color values are not important, a uniformly faint illumination would prove sufficient, but for the glare of advertising signs and automobile headlights. With these factors street illumination must be brought up to a decidedly higher standard than was necessary a few years ago. Since reflection cannot be relied upon for diffusing the light of street lamps, they must be placed near enough together, so that every object will be lighted by at least to lamps. At present a spacing of about 100 feet is regarded as satisfactory, but shorter intervals would be better.

Lamps are most effective when high above the street, unless foliage interfere with their lighting. The size and position of objects is judged somewhat by shadows, and normal daylight is from above. Detroit and some other cities at one time tried the experiment of placing groups of arc lamps at the tops of tall masts with reflectors for directing downward powerful rays. The waste of light which fell upon the roofs of buildings, and the interference of trees caused this promising scheme to be abandoned. A modification, consisting in placing lamps with reflectors at the cornice line of buildings on a treeless street, could be used successfully, but owing to the variable height of

buildings, and to local difficulties this plan would not be generally available. Posts carrying street lamps should be as tall as daylight appearance and cost will permit. If lamps are hung over the roadway they should be at least 25 feet high, so as not to cut off the view beyond.

It is usually assumed that an object must be illuminated to be seen. Another method of vision relies upon contrast, showing an object when it obscures a portion of a bright background. While less satisfactory, this method should be borne in mind in planning street lighting, especially if cost prevents the placing of lamps as near together as would be desirable. Coupled with the recognized fact that a lamp when out of doors appears more glaring than when indoors, lamps placed on the outside of a long curve in a road will be decidedly more effective than if placed on the inside of the curve, showing the way much farther ahead, and displaying vehicles on the roadway. When a street joins another without crossing it, a lamp placed opposite the end of the incoming street will leave a clear view around the corners.

Lamps provided with diffusing globes are much more satisfactory than when used clear. The common belief that globes dense enough to cut off from view the brilliant lamp filament are very wasteful of light is not true, because in the absence of glare the normally open pupil allows better vision than the pupil contracted by glare permits, even with additional light. A photometric measurement of illumination is no criterion for distinctness of vision. There are two types of diffusing shades, the ordinary opal globe, and the scientifically moulded prism glass shade. The latter directs a powerful ray in a predetermined direction, and thereby obtains a more effective utilization of the power of the lamp. The particular need for such directing shades is when lamps are far apart. With powerful lamps such shades being of relatively small surface are apt to appear glaring, and lamps of less power than those usually prescribed by shade manufacturers are preferable. With opal globes there is complete diffusion without possibility of directed rays. Globes should be in proportion to the candle power of the lamps they enclose, so that the surface brilliancy of the globes may be uniform. The largest of such globes, 18 inches in diamenter, have too great a brightness if lamps larger than 250 watts are used therein.

Modern tendencies indicate the waning of the 5-light and 3-light cluster standards in favor of the more elegant single globe on a slender post. The common objection to using a single lamp per post, that it may burn out, is not important with the great

length of life of standard lamps. With lamps at short intervals a single out will not be serious in any event. The best effects in street illumination may be obtained by placing lamps very close together, reducing the candle power of each lamp. Lamps may be suspended from an artistic beam extending along the street upon appropriate posts. This would permit, indeed demand, the use of aboveground wiring at considerable saving in first cost. The arrangement should be planned for daylight effect as well as for use at night. It is not strictly essential that lamp posts should be symmetrically arraged. Where a public building is involved its entrance should be emphasized by a suitable grouping or alignment of the lamps. If lamps are arranged unsymmetrically for an adequate reason, that reason will make the arrangement artistic.

PULL AND FLUX CHARACTERISTICS OF A SOLENOID

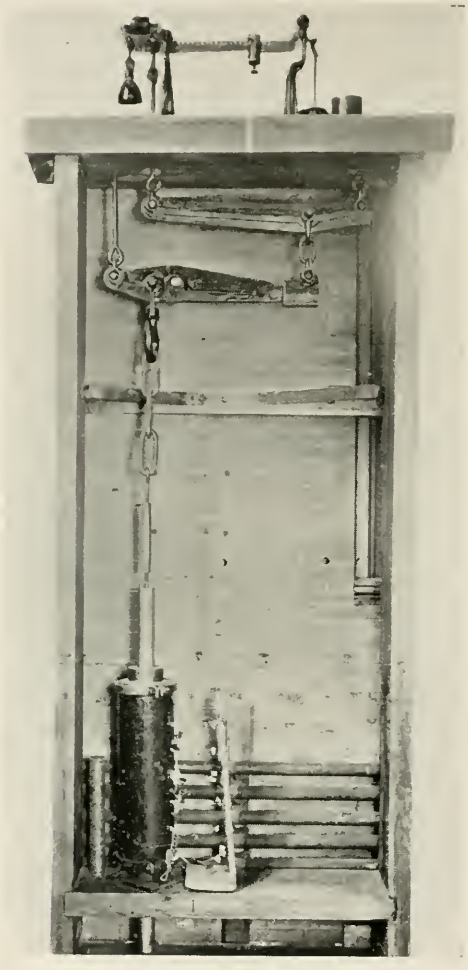
E. A. REID

A review of the literature on the subject of solenoids seemed to indicate that no great amount of actual experimental work has been published, especially upon large solenoids. Moreover, although certain authors have assumed certain flux distribution and have divided the resultant pull into components for the purpose of computation and discussion, no data on actual flux conditions in the winding are available.

A description of the apparatus and the methods used in some research along these lines may be of interest. The tests herein described were made in the Electrical Engineering department of the University of Illinois in the spring of 1915, upon a solenoid built there and designed for a maximum pull of 800 pounds. They covered pull characteristics and flux distribution under various conditions.

The winding consisted of six sections, each having an outside and inside diameter of 6 inches and 2⅛ inches, respectively, and a height of 3 inches. Each section contained 2000 turns of No. 17 B. & S. gage double cotton covered wire. A knockdown form was constructed and mounted upon the shaft of a small series motor, the speed of which could be controlled by the tension upon the wire. By this means, the coils were wound very rapidly and smoothly and of uniform size. After being removed

from the form the sections were covered with white cotton tape, baked at about 90 C. for twelve hours, then soaked in shellac for the same length of time, and dried for another twelve hours in the oven. The coils maintained their shape perfectly; were well



insulated, and were capable of withstanding fairly rough handling. For the tests discussed in this paper, the six sections were connected in series and slipped over a brass tube of 2-inch inside diameter and 1/16 inch thickness.

The plunger and stop were made of commercial wrought iron, turned to a sliding fit within the brass tube. The plunger was

made 22 inches long in order that it could extend through the solenoid so that data could be obtained for all positions. The stop could be varied in length up to the center of the winding.

In order to make the solenoid ironclad, a shell was made of 6-inch wrought iron steam pipe, cut to a 21-inch length and bored out to a smooth finish inside. Heads were cast and turned down to a tight fit. The brass tube passed through the upper head but merely entered the lower far enough to be held rigidly in place.

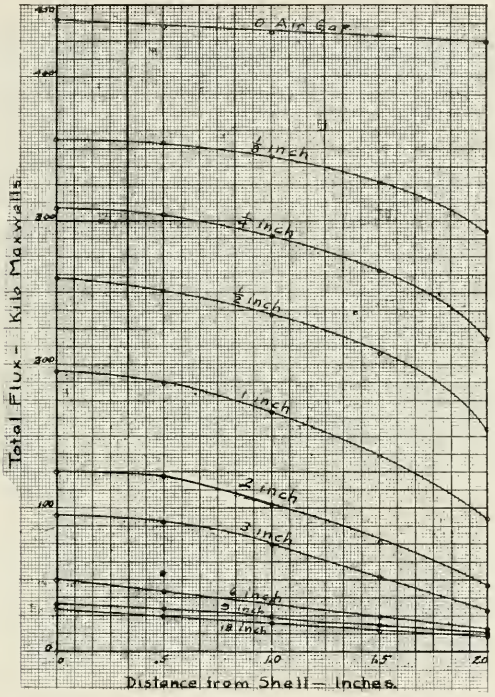


FIG. 1.

Shell and heads were slit and clamped tightly together so that the only air gap in the magnetic circuit was the 1/16-inch brass shell between the plunger and the upper head. The area of this gap, as well as the area of the entire path, was made large, so that its reluctance was negligible in comparison with any air gap between plunger and stop greater than 1/8-inch.

In order that the pull might be measured with the plunger in any position within the solenooid, and with as little friction as possible, the scale beam was placed very high. Then by means of chain links and a turnbuckle, the position could be varied from top to bottom by increments as small as 1/32 of an inch. The ac-

companying cut (Page 90) shows the apparatus with the plunger about half in the solenoid. The scale used to measure the pull had a capacity of 1100 pounds by one pound increments.

In addition to the pull characteristics, it was desired to ascertain what portion of the flux leaked out through the coil with various air gaps, and for this purpose it was desired to measure the flux in planes both parallel with and perpendicular to the plunger axis. The plunger area was 19.6 sq. cms., hence a minimum flux

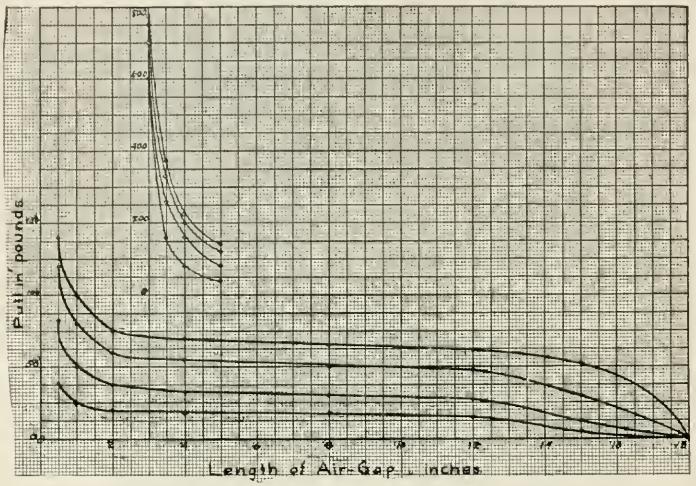


FIG. 2

of about 400,000 lines was assumed. Since a Grassot fluxmeter having a minimum range of 1,000,000 linkages was to be used, a single turn of wire for each search coil was sufficient. The problem of placing and holding these turns in place within the coil was solved by sewing No. 36 double silk covered wire into thin varnished cambric cloth, cut to fit over the brass shell and inside the iron shell. Five search coils were placed 1 inch apart in each sheet, and a sheet placed between each two sections of the solenoid and between the winding and each head. This gave a total of 35 positions from core to outside and from top to bottom of the solenoid where the actual flux under various conditions could be accurately determined. The method of taking these readings was as follows:

The current in the main coil was built up to the desired value and the switch opened with the fluxmeter connected to the particular search coil. The fluxmeter was then short-circuited, and the needle remained near the point of highest deflection. The switch was then closed on the main coil, the short circuit opened,

and the switch quickly reversed. The reading obtained was due to the flux dying out in the coil and building up in the opposite direction. Half of this reading was the true value of the flux cutting the search coil. The advantage of reversing the excitation is evident, since otherwise the difference between total flux and residual would be obtained, instead of the total flux. Since the flux meter reading does not depend upon the resistance of the circuit, nor upon the time of opening nor closing the switch, it can be seen that this method of measuring the flux is very accurate.

Pull characteristics were obtained first with the stop fixed so that its upper surface was flush with the lower end of the coil and the plunger varying from a position in contact with the stop to a position just entering the coil. That is, the air gap was varied from zero to 18 inches, its length being 1/8, 1/4, 1/2, 1, 2, 3, 4 8, 12, 15 and 18 inches in turn. These tests were repeated with the stop projecting into the coil 1/16, 1/3 and 1/2 the coil length. Flux readings from each of the 35 search coils were taken for each position.

The scope of this article is intended to be largely descriptive of the method of construction and testing to obtain the desired data, hence no serious attempt will be made to discuss the results obtained. Sixty-five curves illustrating pull characteristic and 102 curves showing flux distribution were drawn from the data obtained. It was noted that the contact pull was practically the same for any position of the stop. This would be expected since the pull is then between two magnets and does not depend upon the position of the magnets in the coil. For small air gaps, however, the pull increased with the length of stop until some point near the center was reached, and then decreased for lengths beyond this. For air gaps larger than ¼-inch, the pull is practically the same for all positions of the stop, except for the position even with the coil. It appears, then, that for best results the stop should enter the coil a short distance.

For air gaps greater than ½-inch the stop has little effect. Unless the pull at the end of the stroke is to be used, the stop is unnecessary. The effective range, that is, the range of uniform pull, is a maximum with the stop just entering the coil. For this position the effective range is about 0.6 the length of the solenoid.

From the flux curves, it was noted that the flux through the stop decreases from 385,000 lines with no air gap to 155,000 lines at ¼-inch gap, 95,000 at ½-inch gap, and 15,000 at 3-inch gap. With further increase of gap, the flux through stop remains about constant. This value is probably the flux through stop and coil, and does not affect the pull. Hence, it is easily seen

why the pull between stop and plunger is negligible after a gap of 1-inch is reached.

Another point noted was that the center of distribution of flux is nearer to the shell than to the plunger. This is more marked near the ends of the solenoid. In other words, the flux near the ends instead of following the iron path through the heads, has a tendency to crowd out through the coil itself.

With increasing air gap, the leakage in the planes through the air gap became very great, while the flux in the planes beyond the air gap fell off very slightly. This bears out the theory that with a given excitation, the density in the plunger remains constant with any air gap whatever. In other words, the sum of leakage and air gap flux is practically a constant.

A set of curves was taken showing the flux in a plane through the center of the air gap, with the center of the air gap always in the center of the solenoid. They show clearly the uniformity of leakage from plunger to shell. Fig. 1 shows these results. Fig. 2 is a typical set of pull characteristics, showing the pull with the stop even with the coil. E. A. REID.

GAS ENGINE IGNITION.

I. W. FISK, E. E. Department

T. KAWAMOTO, Graduate Student

There are many different schemes used at the present time to ignite the gas or gasoline vapor within the cylinders of internal combustion engines. They may, however, be divided into four general classifications, as follows:

1. Low tension magneto-battery.
2. Low tension make and break.
3. Multiple vibrators and master vibrators.
4. High tension magneto.

A complete analysis of the above methods of ignition is beyond the scope of this paper which will deal only in a general way with the last three systems mentioned above and show the results of some experiments conducted on the low tension magneto battery circuit.

In all automobile work at the present time the gas within the cylinders is ignited by means of an electric spark, this spark is produced at the stationary plug points at the proper instant by the application of a high voltage, the time of application being controled by the engine timing mechanism.

Since the present sources of constant potential, such as dry cells or storage batteries, are necessarily of low voltage and since the direct generation of a high voltage by means of a magneto is impractical it is evident that, to produce the high voltage needed at the spark plug points, some other link must be added to the circuit. For this purpose the automobile ignition coil or transformer has been developed, the operating principle of which is as follows:

Suppose a coil of wire wound on an iron core and the ends of this coil be connected to a source of varying potential, then a current will flow therein which will also be varying in its intensity and will cause the iron core to become magnetized or carry lines of magnetic flux, Φ, nearly proportional to the current strength. The change in value of this magnetic flux, Φ, produces an electric-motive force or voltage which is proportional to the number of turns of wire on the coil and to the time-rate of change of the flux. This law may therefore be written

$$e_1 = N_1 \frac{d\Phi}{dt} \quad \ldots\ldots (1)$$

where e_1 = the induced voltage, N = the number of turns of wire in the primary coil and

$\frac{d\Phi}{dt}$ = the time rate of change of the magnetic flux.

However, the direction of this induced voltage is opposed to the direction of the current producing it and therefore equation (1) is written

$$e_1 = -N_1 \frac{d\Phi}{dt} \quad \ldots\ldots (2)$$

If, now, a second coil, or secondary winding of N_2 turns, is wound on the same iron core a voltage must be induced in this coil since it links with the same varying flux as the primary coil, the voltage induced therein must be

$$e_2 = -N_2 \frac{d\Phi}{dt} \quad \ldots\ldots (3)$$

Thus it is seen that the voltages induced in the two coils are directly proportional to their respective number of turns, or

$$\frac{e_1}{e_2} = \frac{N_1}{N_2} \quad \ldots\ldots (4)$$

The equation (4) shows that, starting with a low voltage impressed on coil 1 a high voltage may be obtained from coil 2 by either of the two methods:

(a) By using a larger number of turns in coil 2.

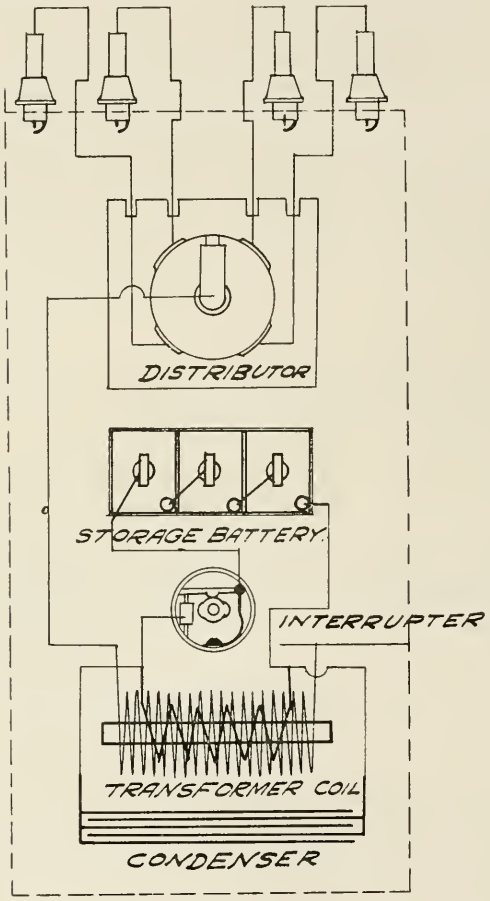


Fig. 1

(b) By producing a high valve of $\frac{d\Phi}{dt}$.

Remembering that the flux Φ is directly proportional to the cur-

rent in primary and that a storage battery or dry cell produces a constant potential, it is evident that some means must be provided to produce a varying curent when these storage batteries or dry cells are used.

This is accomplished by placing in series with the primary coil and source of potential an interrupter which in most systems closes the primary circuit for a given length of time during each revolution and interrupts this circuit when the high tension spark is desired.

In Fig. 1 is shown a wiring diagram of such a system widely used with various automobile engines at the present time.

The operation of the circuit shown in Fig. 1 is as follows:

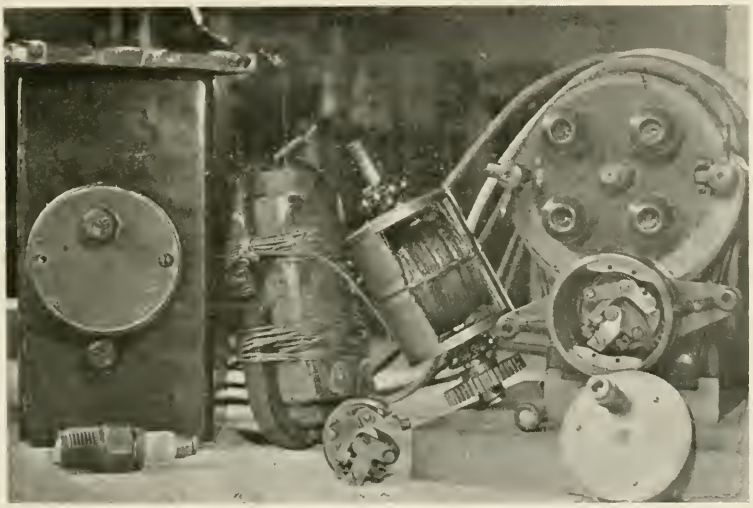


FIG. 1a.

On rotating the engine the interrupter moves to a position where the circuit is closed and a current flows into the primary coil. This current produces a flux proportional to the strength of current, but as the engine is still further rolated the primary circuit is interrupted; the current and flux rapidly fall to zero, thus inducing a high voltage in the secondary coil which in turn causes a spark to jump across one of the engine plugs to the frame of the car and thence through the frame to the ground connection of the secondary coil. This process is repeated as the engine rotates, excepting that on each successive break the distributor has moved so as to connect the secondary with the proper engine cylinder. Fig. 1a shows the mechanical con-

struction of this system. In it are shown the primary and secondary coils wound on the iron core. In the extreme front of the picture is shown the interrupter while at the right may be seen the interrupter in position, with the distributor box just above. The distributor and interrupter are connected through gears to the engine shaft. The four connectors attached to the distributor box are the points to which the cylinder leads are to be connected, while the center point leads to the secondary winding as shown in the wiring diagram of Fig. 1.

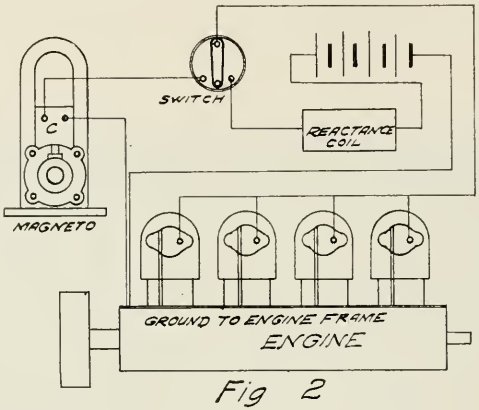


Fig 2

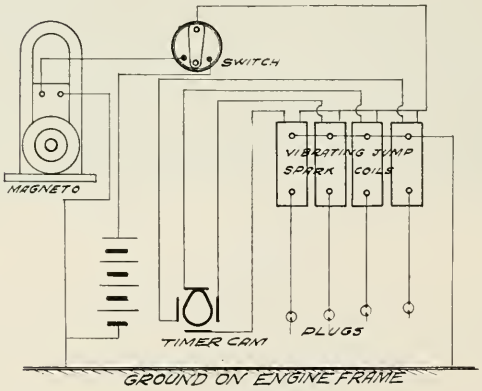


Fig. 3

Fig. 2 illustrates the low tension make and break system used generally on low speed farm engines and operates as follows: The circuit is closed by means of a cam motion and interrupter, this interrupter being located within the cylinder walls. On rotating the engine, the circuit is closed and the current flows from the battery through the reactance coil and interrupter.

The current continues to flow until the position of the piston is correct for firing the charge of gas, at which time the interrupter is opened and a fat low tension spark is produced at the points of the interrupter. The function of the reactance coil is to store

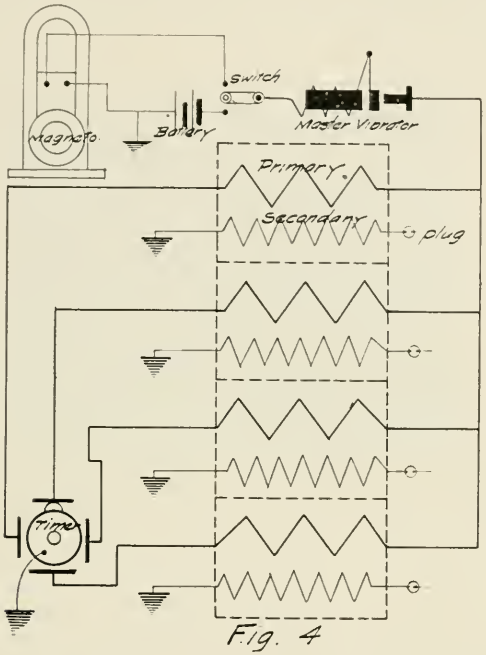


Fig. 4

energy while the circuit is closed and dissipate it at the interrupter points when the circuit is opened.

Fig. 3 illustrates an application of the induction coil, which consists of primary and secondary coils wound on an iron core,

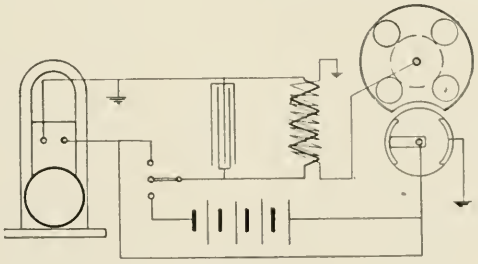


Fig. 5

the primary current of which is interrupted by a vibrator, actuated by the magnetic pull of the iron core. When the position of the piston is such that the charge is under compression and

ready to be ignited, the timer cam closes the primary circuit of the coil connected to this cylinder. The closing of this circuit immediately causes the vibrator to open and close the primary circuit very rapidly, thereby varying the primary current. This variation of primary current induces an e.m.f. in the secondary which is sufficiently high to cause a spark to jump across the gap of the cylinder plug. This system has the disadvantage that it is almost imposible to make all the vibrators and coils equally

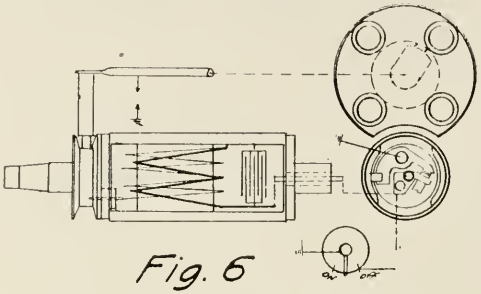


Fig. 6

sensitive, and consequently difficult to obtain the same timing for all cylinders. For this reason, the system in Fig. 4, and known as the master vibrator with multiple coils, has been developed. This system operates exactly the same as the multiple vibrators system except that one vibrator is made to interrupt the primary circuit of all four coils.

Fig. 5 shows the diagram of connection similar to all systems employing the storage battery or dry cell in connection with a low tension magneto. The operation of this system is identical with that system shown in Fig. 1, excepting that, by proper switching of the primary circuit, either the battery or the magneto may be used as the low voltage source of electrical energy.

The high tension magneto is the most recent developement in magneto design. See Fig. 6. The windings of the secondary coil are placed directly on the magneto armature, with the proper insulation between turns. Thus the magneto serves both as a generator and transformer. It is more efficient than the ordinary low tension magneto, for it eliminates those losses due to the primary coil and transformer, and occupies less space.

Fig. 7 and 8 are oscillograms which show some of the operating characteristics of the system illustrated in Fig. 1 Fig. 7 shows, as ordinates, the growth and decay of primary coil current, charging and discharging currents of the condenser, and the magnitude of high tension spark current, when the engine and interrupter are operating at 300 R.P.M., while the abscissa represents time.The interrupter is constructed in such a way that

it will open the primary circuit twice during each revoltion of a four-cyclinder engine, or the time elapsed for a complete operation of the ignition coil shown in Fig. 7 is one-tenth of a second. The upper curve in Fig. 7 shows the growth and decay of the primary current which is started at the time indicated (1), growing gradually to a constant value at (2), here the circuit is inter-

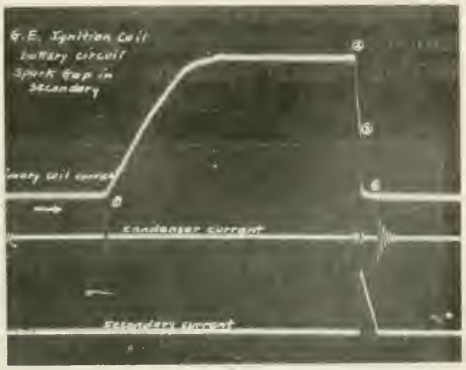


FIG. 7.

rupted by, and the current falls to the valve indicated by (3), and thence very rapidly to the valve shown at (4). The lower curve shows the current conditions in the spark plug circuit. It may here be seen that, during the slow rise of current from (1) to (2) and also the relatively slow decay of current from (2) to (3) in the primary coil, that the voltage of the secondary has not reached a value sufficiently high to force current across the spark plugs. However, from time (3) to (4) the decay of current in primary and hence the rate of decrease of flux in the core

$$\frac{d\Phi}{dt}$$

is very nearly instanteneous and the term reaches such a

$$\frac{d\Phi}{dt}$$

value that e_2, which is equal to N_2, is great enough to force the current to flow in the secondary circuit or across the spark plugs as shown by the lower curve. After the secondary current has died away, further decay of the primary current assumes an oscillatory form the magnified view of which may be seen in the middle curve.

Fig. 8 illustrates exactly the same conditions as shown in Fig. 7 except that the speed of the apparatus has been increased to 1200 R.P.M. It will here be noticed that the primary current

does not reach so high a value as in the case shown in Fig. 7, and also that the spark gap current is very much reduced. This seems to be contrary to the belief of most automobile drivers who think that the higher the engine speed the greater should be the spark current. However, this is not true when working over wide ranges of engine speeds, but for all moderate speeds there is still ample time for the primary current to reach a sufficiently high value to give good practical ignition.

An explanation of these phenomena are made simpler when seen from the mathematical equations. Thus, from Kirchhoff's

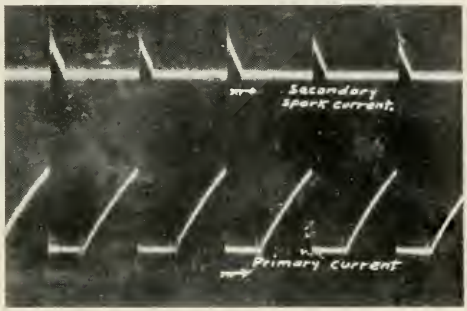


FIG. 8.

law, we know that the algebraic sum of voltages and i r drops in any closed circuit must be equal to zero, or, in case of growth of current in any circuit similar to the primary circuit shown in Fig. 1,

$$E = i\,r + L\frac{di}{dt}$$

where E is impressed e.m.f., $L\frac{di}{dt}$ is induced e.mf., and i r is voltage drop due to the resistance. The solution of the above equation is

$$i = \frac{E}{r}\left[1 - l^{\frac{r}{l}-t}\right]$$

From this equation we see that theoretically an infinite time is required for the current to reach the steady valve $\frac{E}{r}$. But in

circuits met with in practice the current will be very nearly equal to $\frac{E}{r}$ in a very short interval of time. It may also be seen from the equation that, with a constant impressed e.m.f., E, the time required to reach the steady value depends upon the ratio $\frac{r}{L}$ or what is known as the time constant. That is the greater the valve of r and smaller the value of L the more rapidly will i reach a valve $\frac{E}{r}$. Therefore, it may be seen that, with a given coil, there must be allowed a certain length of time for the current to build up to some valve sufficiently high to cause a secondary discharge when the circuit is interrupted. This fact is clearly illustrated in the Figs. 6 and 7. In the former it is evident that the current has reached its maximum valve while in the latter the current was interrupted before attaining this condition. The result of this high speed is that the spark gap or secondary current has been materially reduced although the induced voltage was sufficient to start this current across the gap.

As has been pointed out previously the primary current undergoes three different conditions during its decay, that is referring to Fig. 7, current decays from (2) to (3) under the first condition which is due to imperfection in the mechanical part of the interrupter and may be avoided to some extent; under the second condition the current decays from (3) to(4), and finally the current dies away under the third condition corresponding to (4) to zero valve of the primary current. This decay of the primary current as well as secondary spark current may be expressed approximately in the form of mathematical equations similar to equation (5). Hoever, the derivations of such expressions is beyond the scope of this paper, hence omitted here.

For purpose of showing the characteristics of such equations the following three expressions represents the decaying current under three conditions described above

$$i = A e^{-at} + B e^{-bt} \quad (6)$$

$$i = C e^{-ct} + D e^{-dt} \quad (7)$$

$$i = F e^{ft} \sin (Gt + H) \quad (8)$$

and the spark current equations assumes the form

$$i_2 = K e^{-kt} + L e^{-lt} \quad (9)$$

where A, B, ... L and a, b, ... l are functions of the constants of primary circuit or both primary and secondary circuits.

SMALL GENERATORS TO GIVE SINE WAVE OF VOLTAGE

C. R. MOORE

E. E. Department

It is not the purpose of this paper to outline the caluclations made in arriving at the designs shown hereafter, but rather to confine the discussion entirely to machines as actually built and the results given by them. In each case it was necessary to make certain calculations and for each construction the expected wave shape was determined. These wave shapes will be referred to as predicted forms.

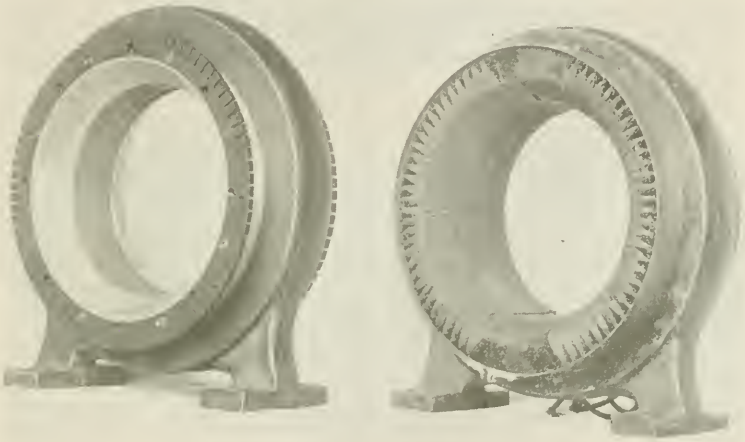
The need for generators giving exact sine waves of voltage and out of which the following experimental work grew came about as a result of the efforts on the part of the writer to construct a mechanical wattmeter, that is a machine which was expected to measure mechanical power directly. The scheme of operation of this device has been described elsewhere* and will be referred to briefly here.

This device as a whole consists of two small single phase alternators connected mechanically by a spring. The two armatures are connected in series with a voltmeter so that at any time the instrument reads the resultant voltage produced by the two alternators. Mechanical power is applied to one of the alternator shafts and delivered by the other with the result that the spring is deflected by an amount dependent on the torque transmitted. The voltages of the two machines are carefully adjusted to equal values, by varying the field current through each. It is obvious that this equality of voltage holds for all speeds since voltage varys directly with speed and from the nature of the design the speeds of the two alternators are always equal. With the machine running light, i. e., no power transmitted, one of the alternator armatures, which is made rotable on the axis of the shaft is turned until the voltage produced by it exactly opposes at all times the voltage produced by the other alternator. Evidently under these conditions the resultant voltage acting on the instrument is zero. If now mechanical power is transmitted the spring deflects allowing the voltage of the alternator on the driven side or side to which power is applied, to move ahead in phase of the voltage of the other alternator by an amount proportional to the tarque transmitted. A resultant voltage is thus set up in the circuit, indicated by the voltmeter. On the assumption that each of the alternators generates voltage waves sinusoidal

*See Elec World, August 31, 1912

in shape it can be shown that the above resultant voltage will also be sinusoidal and that the effective value of this resultant will be proportional to the product of the angle of deflection and the speed, is proportional to the mechanical power transmitted* The scale of the instrument may thus be made to read watts, or horsepower transmitted directly, no calculations being necessary.

It is evident that if the above theory is to be worked out satisfactorily in a practical machine it is necessary that each of the two alternators gives an exact sine wave of voltage. It is not enough that the waves be what is ordinarily termed "practically a sine wave" since the resultant voltage acting on the instrument



a. FIG. 1. b.

is small compared to that of either of the alternators producing it. In a practical machine the resultant voltage should not exceed 40 per cent of the voltage of either alternator. This means that slight irregularities on the main waves which would ordinarily pass unnoticed are magnified in the resultant wave; a fact particularly important for the smaller values of resultant voltage.

The choice of design for these alternators, therefore, hinges mainly on wave form although there are other considerations which will be pointed out later. As commercially built alternators may be classified as follows, (a) revolving armature type and (b) revolving pole type. For this design (b) was chosen since with this type there would be no moving contacts in the voltmeter circuit—a very desirable feature. This point having been settled there remained the choice of the type of armature. Alter-

*The limiting angle allowing error of one percent is about 25 degrees.

nators are successfully built either with smooth core armatures or with slotted laminations, the latter giving the cheaper machine for the same output but with poorer wave form* Since output is not an element in this consideration the smooth case armature was chosen.

In Fig. 1, (a) shows the armature ready for winding, and (b) the armature after the winding has been put on. The winding may be put on in such a way that each conductor is parallel to axis of the shaft or skewed. The former will be known as a "straight" and the latter a "skewed" winding. Both were tried the view (b) being that of an armature wound "straight." The amount of the armature surface to be covered by conductors will be discussed later.

Revolving polar structures may be built in two ways, i. e., with "concentrated" and with distributed winding. In the former

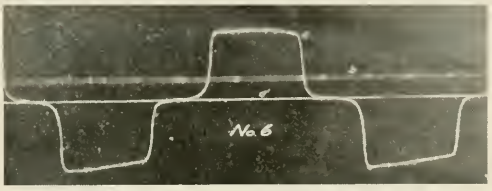
a. FIG. 2. b.

the field coils encircle the entire flux per pole and the proper distribution of flux density is secured by means of a suitably shaped pole piece or "shoe." In the latter the field coils are distributed so that each field coil does not encircle the entire flux set up. There is no pole shoe, the iron portion of the polar structure being a simple drum or disk circular in shape and with slots cut in its periphery. The exciting coils are placed in these slots and connected in such a way that definite magnetic poles are produced. The proper distribution of flux density is obtained by suitably grading the number of conductors placed in each slot. Both the above types of poles are built successfully in practice and each may be made to give definite flux distribution. Hence the choice is not simple.

Fig. 2 shows views of each of these types of polar structure

*In an early machine the author built a slotted armature alternator but with poor results.

(a) being of the "concentrated" and (b) of the "distributed" type. The former was built first, the intention being to secure the proper flux distribution experimentally by shaping the pole shoes at the tips. As will be pointed out later such shaping while practical involved experimental work to such an extent that it was thought best to try the distributed type before proceeding. The reasons will be given shortly.



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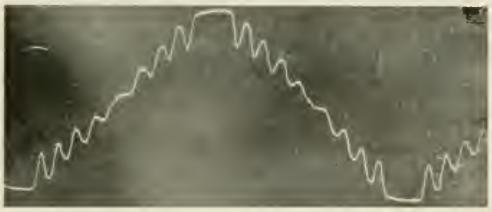


(*b*)

Fig. 3.

Flux Distribution Curves

Of prime importance in choosing the better type of pole is the flux distribution over the armature face given by each of them. This was determined by means of an oscillograph and a small test coil wound around the armature case. In Fig. 3, (a) shows the flux distribution given by the concentrated pole. It will be noted that this curve is more or less rectangular in shape, the sharpness of the upper corners being dependent upon the shape given the pole shoe and the magnetic saturation of the pole tips. In order to make these machines small in diameter, high magnetic densities were employed, and the pole tips were necessarily made rather sharp to find room for the exciting coils. For these reasons the original pole did not give the predicted flux distribution. Furthermore it was found that shaping the pole tips did not have the usual effect. Experiment showed that whereas shaping the pole tips modified the upper corners and the height of the flux wave it did not materially change the flux densities

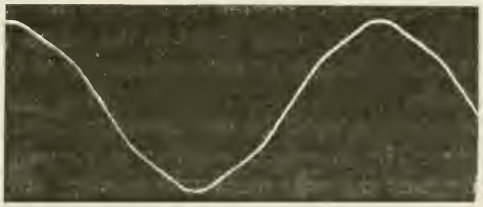
in the space between the pole tips i.e. the shape of the curve near the zero line was unaltered.

It will be noted that the outer edge of the exciting coils run very closely to the armature surface, a fact which limits the spread of the flux, since the magnetizing coils must encircle the flux set up. Therefore to secure the necessary flux densities in the space between the pole tips it would have been necessary to change the form and dimensions of the magnetizing coils, a condition which so far as the writer is aware has not occurred in alternator construction. We may therefore say that the shape of the flux distribution curve given by the "concentrated" type of pole depends upon the magnetic saturation of the pole tips, the shape of the pole shoe, and the position of the exciting coil.

It was thought that instead of making the changes indicated, an easier solution would be to use the "distributed" type of pole. Some further experiments were made, however, to determine what improvement in wave form of voltage might be expected, using the concentrated pole if armature windings covering various percentages of the pole pitch were employed. In Fig. 4 (a) and (b) and in Fig. 5 (a) are shown three oscillagrams chosen from several taken, the only variables being the spread of the armature winding and the manner of placing the individual conductors is whether wound, skewed or straight. To obtain curve (a) Fig. 4 the armature was wound "straight," the spread being 59 per cent of the pole pitch or equal to the width circumferentially of the pole shoe. This curve agrees closely with the predicted voltage curve in which prediction the actual flux distribution (a) Fig. 3 was used. Curve (b) Fig. 4 shows the voltage wave given when the armature conductors cover 64 percent of the pole pitch and curve (a) Fig. 5 shows the form of voltage when the winding covers 75 per cent of the pole pitch. These voltage curves all appear to be made up of practically straight lines, a fact that appears reasonable from the shape of the flux curve. The first voltage curve is pointed, and second and third flat at the top. Further increase in spread would have only increased the width of the flat portion at the top. Experiments similar to the above were also made with windings put on "skew" fashion but the effect was slight. The results indicated that there was little to be hoped for in altering the spread of the armature winding and that the flux distribution curve must be changed. The voltage curve (a) Fig.5 given by the concentrated pole and a spread of armature winding of 75 per cent is sinusoidal in general form but the corners are prominent and these affected the form of the resultant voltage curve considerably.

The design of the distributed pole was based upon sinusoidal

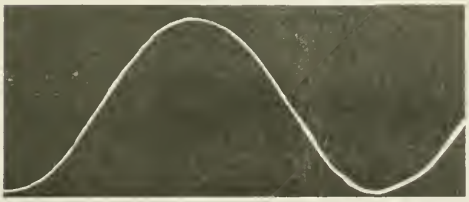
flux distribution, that is the size of the slots; spacing and number of conductors each were to contain wire so planned that the m.m.f. produced by each slot in succession increased, or decreased



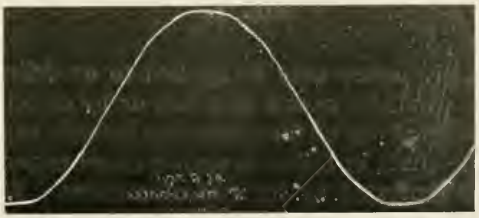
a.

b.

FIG. 4.



a.



b.

FIG. 5.

A view of this pole is given in (b) Fig. 2, according to the sine law. The flux distribution given by this pole is shown in (b) Fig. 3. Owing to the slotting this curve as predicted is irregular but in general form it is sinusoidal. Furthermore these irregularities do not appear in the voltage wave since the "skew" of the armature winding may be made equal to the width of the slots. This skewing has the effect in any one conductor of bridging over these irregularities.

In Fig. 6 is shown a view of the alternator equipped with a distributed pole. The armature winding is skewed and covers about 70 per cent of the pole pitch. In passing, attention might be called to the driving pulley on the left, the clamping screw at the top of the armature and the "squirrel cage" spring on the

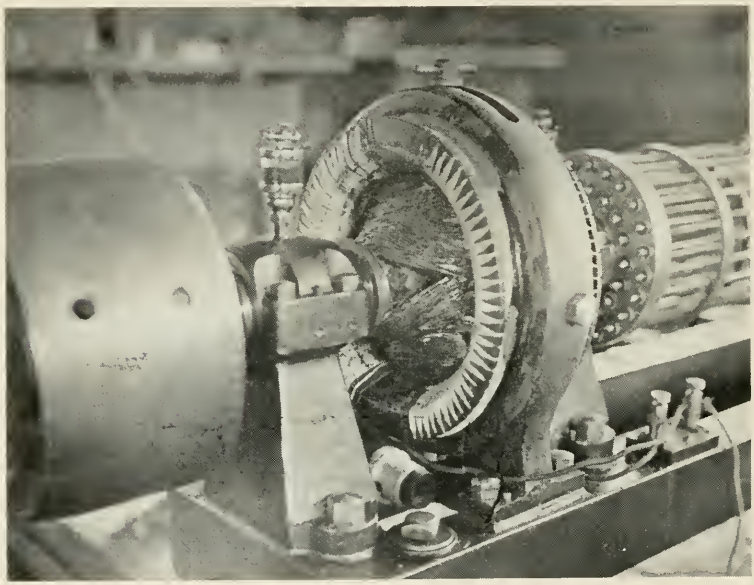


FIG. 6.

right. Obviously power may be applied to or delivered by the machine as a whole by means of a belt or by direct connection. As previously stated one of the armatures is made rotatable about the axis of the shaft in order to secure exact opposition of the equal voltages generated by the two alternators. The clamping screw at the top provides means for holding the armature in position after such adjustment has been secured. The spring at the right is made up of parallel steel rods and allows one alter-

nator to lag behind the other when mechanical power is transmitted. This spring has been described elsewhere.*

The voltage wave produced by the alternator shown in Fig. 6 is given in (b) Fig. 5. This wave is sinusoidal as nearly as the oscillagram can be measured, such measurements indicating an average deviation of about 2 per cent from the true sine curve. Since this error is smaller than errors inhirent in such measurement, only the performance of the completed power meter can indicate whether further improvement in wave form is necessary.

*See American Machinist.

GRAPHICAL DETERMINATION OF VOLTAGE AND FLUX WAVES

A. R. KNIGHT

1. Voltage Wave from Flux Wave.

When a magnetic flux, linked with an electric circuit, varies, a voltage is induced in the circuit which is proportioned to the number of turns of wire through which the flux links and to the time rate of change of the flux. Expressed as an equation the relation is

$$e = -n\, d\Phi/dt \times 10^{-8} \quad (1)$$

where e is the instantaneous value of the voltage, n the number of turns, and $d\Phi/dt$ the rate of change of flux. The negative sign is used because the induced voltage is of the nature of a reaction. If the average voltage during any period Δt is wanted it can be easily proven to be

$$e_{av} = -n\Delta\Phi/\Delta t \times 10^{-8} \quad (2)$$

where $\Delta\Phi$ is the change in flux in the time Δt.

The variation of flux with time can be represented by means of a curve and is the variation is periodic, as is the case when a coil is rotated in a magnetic field or when the flux is produced by an alternating current, the curve will have the general appearance of a wave and is therefore spoken of as a flux wave.

If the equation of the flux wave is known it is a comparatively easy matter to obtain the equation of the induced voltage by the use of equation (1). But if the equation is not known, and this is true in all cases where the wave is determined experimentally, it becomes necessary to do the work graphically. In this method the flux wave is considered as made up of a series of straight lines and thus of a series of portions for which $d\Phi/dt$ is constant. If $d\Phi/dt$ is constant it will equal $\Delta\Phi/\Delta t$ and use can be made of equation (2). A numerical case is worked out to illustrate the method.

A flux wave whose values are given in Table I is linked with a coil of 400 turns. Determine the wave of induced voltage.

TABLE I

Time (sec.)	Flux (lines.)	Time (sec.)	Flux (lines.)
0	0		
.001	33000	.021	−33000
.002	62000	.022	−62000
.003	83000	.023	−83000
.004	96000	.024	−96000

.005	100000	.025	−100000
.006	98000	.026	−98000
.007	90000	.027	−90000
.008	80000	.028	−80000
.009	73000	.029	−73000
.010	71000	.030	−71000
.011	73000	.031	−73000
.012	80000	.032	−80000
.013	90000	.033	−90000
.014	98000	.034	−98000
.015	100000	.035	−100000
.016	96000	.036	−96000
.017	83000	.037	−83000
.018	62000	.038	−62000
.019	33000	.039	−33000
.020	0	.040	0

During the first interval, from t=0 to t=.001, the flux changes from 0 to 33000. $\Delta\Phi$ and then equals 33000–0 or 33000 and Δt equals .001. The average voltage induced during this interval is $-400 \times \frac{33000}{.001} \times 10^{-8} = 132$ volts. In the second interval $\Delta\Phi =$ 62000–33000=29000 Δt=.001 as before and the average voltage induced during this interval equals $-400 \frac{29000}{.001} \times 10^{-8} = -116$ volts. In like manner the average voltage induced during each interval is found and the result plotted.

Since by this method the average voltage for each interval is found, or in other words the voltage is considered constant during the interval, the results when plotted give a series of horizontal straight lines. A close approximation to the actual curve can be obtained by drawing a smooth curve through the middle points of the straight lines.

The calculation of each interval is given in Table II and the results are shown in Fig. 1.

TABLE II

Interval.	$\Delta\Phi$	$\Delta\Phi \div \Delta t$	Av. Voltage.
0 to .001	33×10^3	33×10^6	−132
.001 to .002	29	29	−116
.002 to .003	21	21	−84
.003 to .004	13	13	−52
.004 to .005	4	4	−16
.005 to .006	−2	−2	8
.006 to .007	−8	−8	32
.007 to .008	−10	−10	40

.008 to .009	−7	−7	28
.009 to .010	−2	−2	8
.010 to .011	2	2	−8
.011 to .012	7	7	−28
.012 to .013	10	10	−40
.013 to .014	8	8	−32
.014 to .015	2	2	−8
.015 to .016	−4	−4	16
.016 to .017	−13	−13	52
.017 to .018	−21	−21	84
.018 to .019	−29	−29	116
.019 to .020	−33	−33	132
.020 to .021	−33	−33	132
.021 to .022	−29	−29	116
.022 to .023	−21	−21	84
.023 to .024	−13	−13	52
.024 to .025	−4	−4	16
.025 to .026	2	2	−8
.026 to .027	8	8	−32
.027 to .028	10	10	−40
.028 to .029	7	7	−28
.029 to .030	2	2	−8
.030 to .031	−2	−2	8
.031 to .032	−7	−7	28
.032 to .033	−10	−10	40
.033 to .034	−8	−8	32
.034 to .035	−2	−2	8
.035 to .036	4	4	16
.036 to .037	13	13	−52
.037 to .038	21	21	−84
.038 to .039	29	29	−116
.039 to .040	33	33	−132

2. Flux Wave from Voltage Wave.

For this determination use is made of equation (2) in a modified form.

$$e_{av} = -n\Delta\Phi / \times 10^{-8} \text{ from which } \Delta\Phi = -1/n \; e_{av}\Delta t \times 10^{8}$$

or the *change* in flux during an interval of time Δt is proportional to the average voltage during the interval and to the time represented by the interval. If the voltage wave is assumed to be made up of a series of straight lines the average value of the voltage during a period is the voltage at the middle of the interval. Then the change in flux during an interval is proportional to the voltage at the middle of the interval.

Divide the axis of a complete cycle of the voltage wave into

equal parts. Consider now the first interval from o to t_1, and let the voltage at the middle be e_1; then the change of flux, $\Delta\Phi$, from o to t_1, equals $-1/n\ e_1\Delta\times 10^8$. In the same way for the second interval, from t_1 to t_2 $\Delta_2\Phi = -1/n\ e_2\ \Delta t\times 10^8$ and for the r^{th} interval $\Phi_r\Phi = -1/n\ e_1\Delta t\times 10^8$. In this way a series of increments of flux is obtained covering the complete cycle. This gives only changes in flux, however, and not the proper data for plotting the flux wave. If the flux at o is assured to be Φ^v the flux at t_1 will be $\Phi^v+\Delta_1\Phi$, at t_2 it will be $\Phi^v+\Delta_1\Phi + \Delta_2\Phi$, and t_1 it will be $\Phi_x + \Delta_1\Phi + \Delta_2\Phi$ .....$\Delta_r\Phi$. By means of this assumption concerning the value of the flux at o all the necessary points on the flux wave are found in terms of Φ_x.

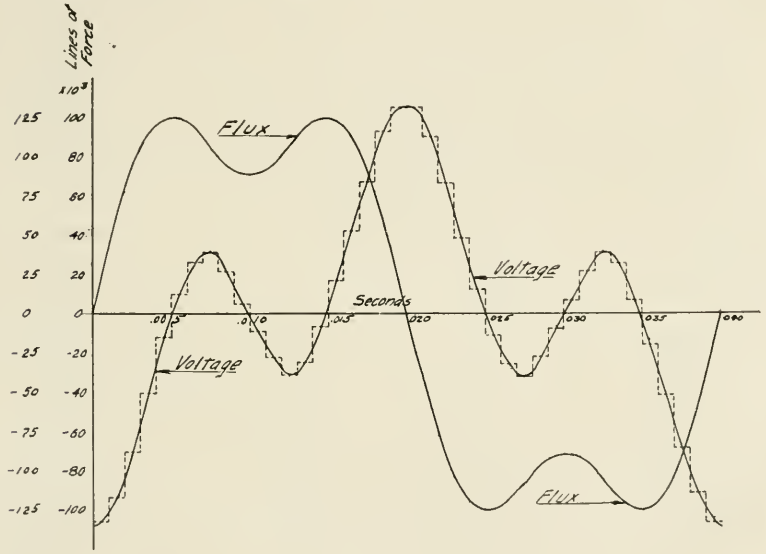


Fig 1

It now becomes necessary to evaluate Φ_x. Its value depends upon manner in which the periodic flux is produced. Since the voltage is induced by a variation of flux it is not necessary that the flux change direction, i. e. it may vary in magnitude periodically but be always in the same direction through the coil and still induce an alternating voltage. Such a flux wave is produced by certain types of inductor alternators or by a make and break type of induction coil operating on direct current. Under these conditions the minimum value of the flux will be known and if this value is equated to the minimum value of $\Phi_x+\Sigma\Delta^m\Phi$ as found above the value of Φ_x is easily obtained. With Φ_x known the value of the flux at each interval is known and the flux wave can be plotted.

If the flux wave is produced by a modern type of alternator or by an alternating current the flux changes its direction through the coil, also the wave will be symmetrical about the X-axis. In this case the value of the flux at the end of the r^{th} interval is equal to minus the value at the end of the $(r+m/2)^{th}$ interval (m being the number of equal intervals into which the axis of one cycle of the wave is divided) or

$$\Phi_x + \sum_{1}^{r} \Phi_n \Phi = -\left(\Phi_x + \sum_{1}^{r+\frac{m}{2}} \Delta_m \Phi\right)$$

Φ_x can be found from this relation and the wave plotted as above.

The following numerical case is worked out to illustrate the method. A voltage wave, whose values are given in Table III, is induced in a coil of 400 turns. Find the flux wave; 1st when the flux is always in the same direction through the coil and has a minimum value of 3500 lines; 2nd when the flux alternates in direction and the flux wave is symmetrical about theX -axis.

TABLE III

Time (sec.)	Volts.	Time (sec.)	Volts.
0	3		
.001	33	.021	−33
.002	62	.022	−62
.003	83	.023	−83
.004	96	.024	−96
.005	100	.025	−100
.006	98	.026	−98
.007	90	.027	−90
.008	80	.028	−80
..009	73	.029	−73
.010	71	.030	−71
.011	73	.031	−73
.012	80	.032	−80
.013	90	.033	−90
.014	98	.034	−98
.015	100	.035	−100
.016	96	.036	−96
.017	83	.037	−83
.018	62	.038	−62
.019	33	.039	−33
.020	0	.040	3

In the solution of this problem (see Table IV) one cycle of the voltage was divided into 40 equal intervals of .001 sec. each, and the voltage at the middle of each interval noted (Column 2).

The change in flux in one interval equals $-1/400\ e\Delta t \times 10^8$, or since Δt is constant, equals $-250e$. The values of $\Delta\Phi$ for each interval was thus found and noted (column 3). From these values those of the total flux were found in terms of Φ_x (column 4.)

The first part of the problem specified flux always in the same direction and with a minimum of 3500 lines. Since Φ_x is assumed positive the minimum flux is at the point where $\Sigma\Delta\Phi$ is maximum

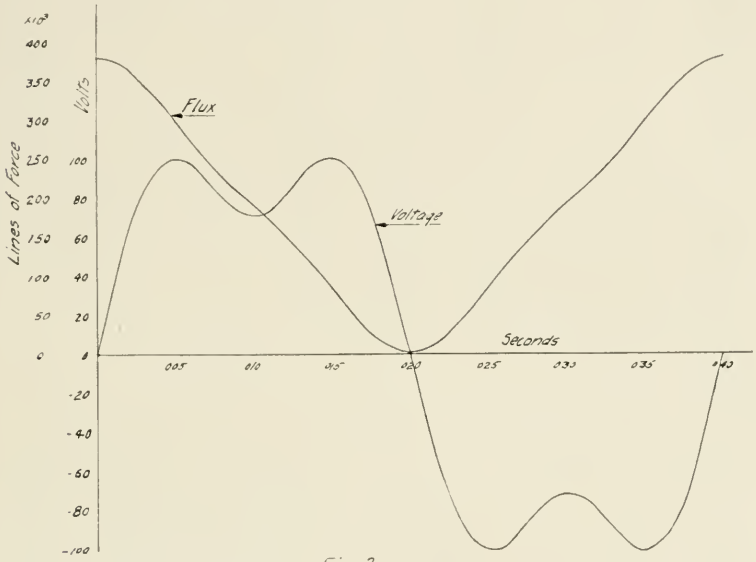


Fig 2

numerically and negative in sign. Inspection of the values of flux shows this to be at the point t=.020 where the flux equals Φ_x–376500

Then Φ_x–376500=3500 and Φ_x=380000.

Substituting this value gives the actual values of flux (column 5).

The second part of the problem specified a flux wave which should be symmetrical about the X axis. In this case the flux at any time t is equal to minus the flux one half period late. The flux at t=.003 is Φ_x34500 and one half period later or at t=.023 is Φ_x–342000.

Then Φ_x–34500=–(Φ_x–342000)

and $\pi\ \Phi_x = 188250$

Substituting this value of Φ_x gives the actual flux (column 6). Fig. 2 shows the voltage and flux waves for the first part of the problem and Fig. 3 the voltage and flux waves for the second part.

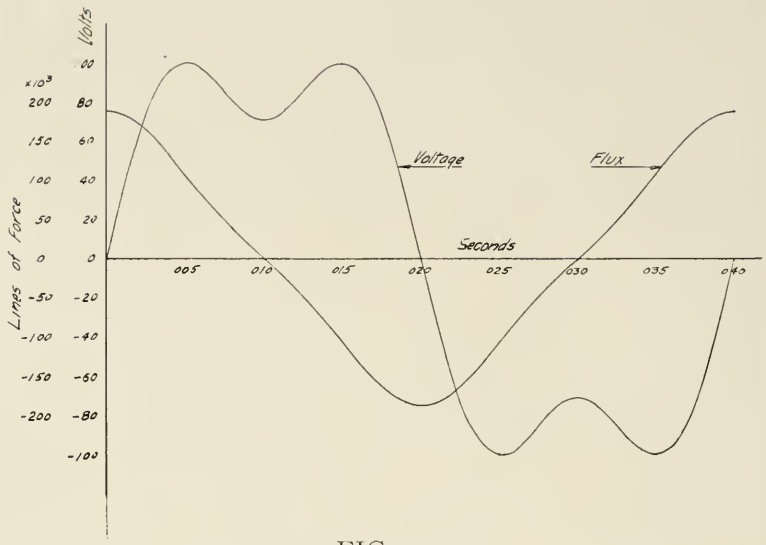


FIG. 3.

TABLE IV

Interval.	Voltage 9+ middle.	ΔΦ	Φ	Φ_1	Φ_2
0 — 001	17	— 4250	Φ_x— 4250	375750	184000
001 — 002	48	— 12000	Φ_x— 16250	363750	172000
002 — 003	73	— 18250	Φ_x— 34500	345500	153750
003 — 004	90	— 22500	Φ_x— 57000	323000	131250
004 — 005	98	— 24500	Φ_x— 81500	298500	106750
005 — 006	99	— 24750	Φ_x—106250	273750	82000
006 — 007	94	— 23500	Φ_x—129750	250250	58500
007 — 008	85	— 21250	Φ_x—151000	229000	37250
008 — 009	77	— 19250	Φ_x—170250	209750	18000
009 — 010	72	— 1800	Φ_x—188250	191750	0
010 — 011	72	— 1800	Φ_x—206250	173750	−18000
011 — 012	77	— 19250	Φ_x—225500	154500	−37250
012 — 013	85	— 21250	Φ_x—246750	133250	−58500
013 — 014	94	— 23500	Φ_x—270250	109750	−82000
014 — 015	99	— 24750	Φ_x—295000	85000	−106750
015 — 016	98	— 24500	Φ_x—319500	60500	−131250
016 — 017	90	— 22500	Φ_x—342000	38000	−153750
017 — 019	48	— 12000	Φ_x—372250	7750	−184000
018 — 019	48	— 1200	Φ_x—372250	7750	−184000
019 — 020	17	— 4250	Φ_x—376500	3500	−188250
020 — 021	— 17	4250	Φ_x—372250	7750	−184000

021 — 022	— 48	12000	Φ_x — 360250	19750	−172000
022 — 023	— 73	18250	Φ_x — 342000	38000	−153750
023 — 024	— 90	22500	Φ_x — 319500	60500	−131250
024 — 025	— 98	24500	Φ_x — 295000	85000	−106750
025 — 026	— 99	24750	Φ_x — 270250	109750	−82000
026 — 027	— 94	23500	Φ_x — 246750	133250	−58500
027 — 028	— 85	21250	Φ_x — 225500	154500	−37250
028 — 029	— 77	19250	Φ_x — 206250	173750	−18000
029 — 030	— 72	18000	Φ_x — 188250	191750	0
030 — 031	— 72	18000	Φ_x — 170250	209750	18000
031 — 032	— 77	19250	Φ_x — 151000	229000	37250
032 — 033	— 85	21250	Φ_x — 129750	250250	58500
033 — 034	— 94	23500	Φ_x — 106250	273750	82000
034 — 035	— 99	24750	Φ_x — 81500	298500	106750
035 — 036	— 98	24500	Φ_x — 57000	323000	131250
036 — 037	— 90	22500	Φ_x — 34500	345500	153750
037 — 038	— 73	18250	Φ_x — 16250	363750	172000
038 — 039	— 48	12000	Φ_x — 4250	375750	184000
039 — 040	— 17	4250	Φ_x — 0	380000	188250

SAFETY FIRST IN SHOP LABORATORIES.

B. W. BENEDICT

Director of Shop Laboratories

It has been estimated that the American people waste approximately $1,5000,000,000 annually through loss of life and illness of industrial workers. Also that a sum in excess of $700,000,000 is annually wasted in losses of income from diseases contracted by workers in performance of their daily tasks.

Wealth is produced by labor in transforming natural resources into forms useful to society. If the processes of transformation are conducted without waste the maximum amount of wealth is produced with a minimum expenditure of effort and society prospers to the utmost. But as wastes creep in to lower the efficiency of these processes more labor is required to create an equal amount of wealth, as less wealth is produced, which throws directly or indirectly a burden on every member of society. These are roughly 33,000,000 wage earners in this country. Their average wage is less than $10 per week. If it were possible to eliminate the wastes from all sources, one authority estimates the wage could be increased to $15 per week for an equivalent expenditure of time and effort. Assuming that the estimated loss of $5 per week to every wage earner is exaggerated and actually it is half that or less, the aggregate loss to society is enormous.

Industry is just beginning to realize the truth that a healthy well trained man working under favorable conditions will do more and better work than one physically unfit and working under dismal, unclean and unsanitary conditions. It has also awakened to a realization that it has some responsibility toward human beings while employing them in gainful occupations. The result has been a widespread betterment of conditions surrounding the worker. More attractive factory buildings and grounds, an increase in natural and artifical light, better water, efficient sanitation and ventilation, adequate protection against accidents, lessening hazard in dangerous occupations, etc. While not all of the existing factories have been remade according to approved methods, it is doubtful if there is one which has not undergone certain changes. Conditions in some quarters still are bad, but they are due to change as they cannot withstand indefinitely the economic pressure of competition from more efficient plants.

The manager of today must understand human beings. He must know how to select them so that the right man will find his proper place. He must understand the basic principles of effic-

ency in order to direct the activities of his workmen through the most profitable channels. He must have vision and breadth of view so that his leadership may be inspiring and forceful. Men that will fit these specifications of the ideal manager are perhaps

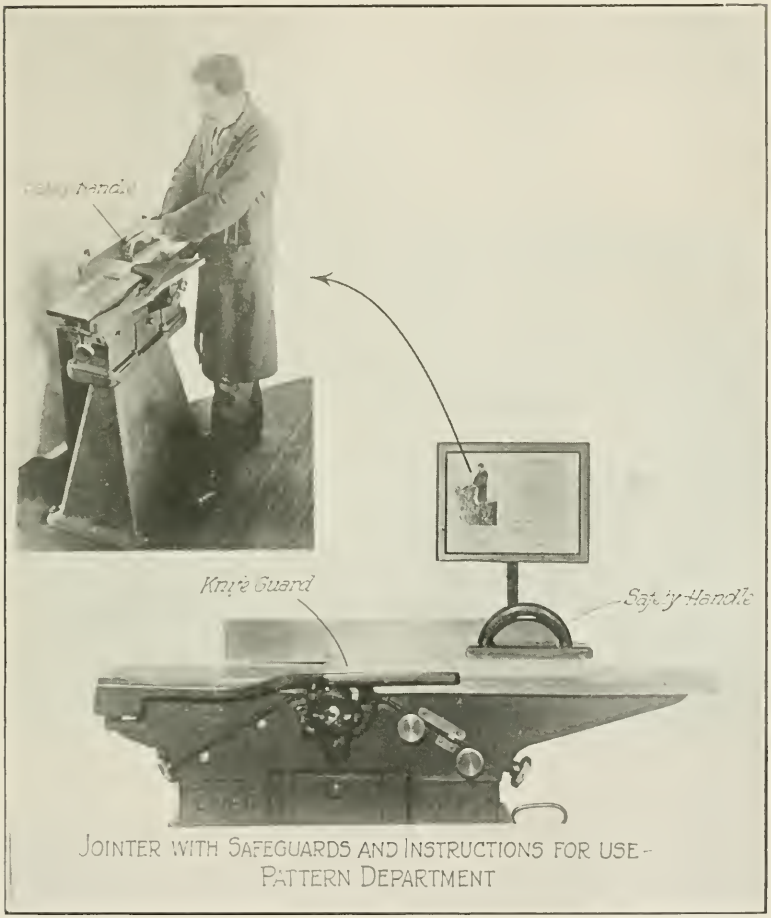


Fig. 1. Typical guard on a very dangerous machine. The guard is automatic. Safety handle and instructions for use of the machine have removed the danger from this machine.

"born and not made." Admittedly, the supply is limited—it probably is non-existant. Men must be trained for the duties of life and all must travel the same path of experience. Some, more gifted, travel faster than others not endowed with equal talents—

but there is no royal road especially reserved for a favored few.

The training of the prospective manager in the broad principles relating to the worker and his task cannot start at too early an age. It should begin in the home and continue throughout school life from the grades to completion of the college course. And of course it is then just begun. The old classical forms of education are built on broader lines than the later technical forms as their ideal is training in the "humanities" while the ideal of the latter is specialized training in the "specialties." And unfortunately in the specialized courses of engineering some of the most important phases of large questions were ignored as seemingly possessed of more human than technical interest. For

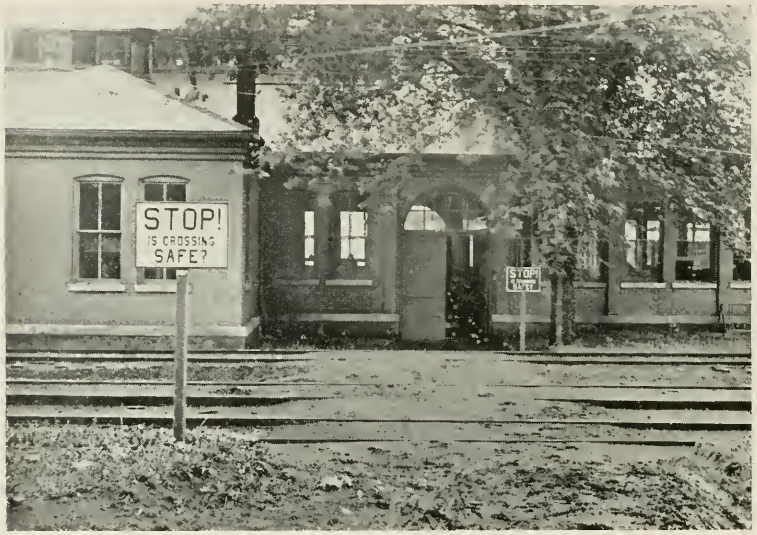


Fig. 2. Warning signs at street car crossings between shop buildings. Student work throughout.

instance shop work was and is administered in many institutions without any or litle relation to the principles of safety. Dangerous machinery was left unguarded and unsafe conditions about the shop permitted to exist. Instruction in safety first principle was unthought of. Reports by safety inspectors show that college shops are generally behind commercial practice in respect to safeguarding machinery and equipment. Most of the college shops personally visited show a lementable disregard for the principles of safety first. To me this seems a very serious defect in educational methods that cannot be explained away by even the most plausible educator.

It is believed that the University of Illinois has taken an advanced stand among educational institutions in the matter of safe-guarding dangerous machinery and conditions in the shop laboratories and also in demonstrating the principles underlying the broad question of safe, sanitary and efficient factory working conditions. The aim has been to eliminate accidents of every description by throwing every possible safe-guard around the

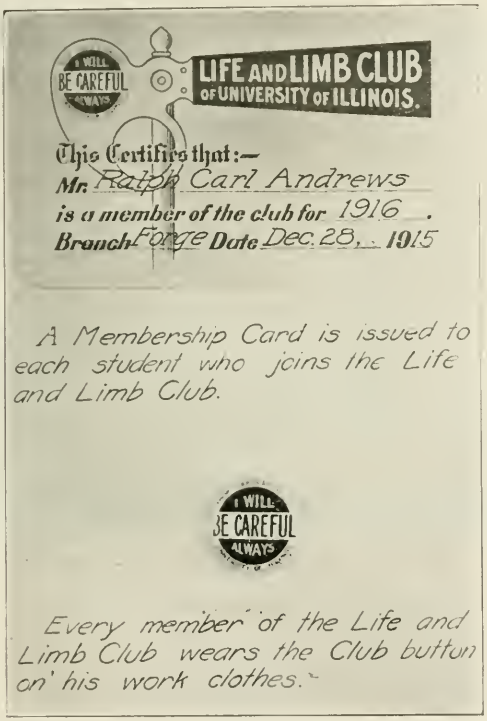

I WILL BE CAREFUL ALWAYS
LIFE AND LIMB CLUB OF UNIVERSITY OF ILLINOIS.
This Certifies that:—
Mr. Ralph Carl Andrews
is a member of the club for 1916 .
Branch Forge Date Dec. 28, 1915
A Membership Card is issued to each student who joins the Life and Limb Club.
I WILL BE CAREFUL ALWAYS
Every member of the Life and Limb Club wears the Club button on his work clothes.

Fig. 3. Illustration showing membership card and button of the Life and Limb Club.

student worker. While some work had been done in applying safety guards to the shop laboratories prior to 1903, an active safety campaign was not initiated until that year. It has been carried on since then as aggressively as funds would permit. Some work remains to be done although the plant is accepted by the department of factory inspection as "safe." A "clean bill of health" in the matter of safety by the State of Illinois carries with it a feeling of satisfaction but it does not modify in the least the original purpose to eliminate every possible source of danger in the shop laboratories, no matter how remote.

Guards of the most approved type have been designed and made by students for all dangerous portions of machinery. A representative guard is shown in Fig. 1. It is applied to a jointer in the pattern department. Complete and definite instructions as to operation of the machine are fastened to the latter and strict compliance thereto required of every student. In addition

Fig. 4. One of the four bulletin cabinets of the Life and Limb Club. The safety first exhibits are frequently changed to sustain interest in the subject of safety

to guards cautionary signs are placed throughout the shops in places where warnings are necesary. Fig. 2 shows representative signs at crossing ones street railway tracks. These signs were designed after consultation with the department of psychology as to the most effective wording. They are constructed entirely of iron and by students.

Records are kept of every injury that occurs in the shop laboratories no matter how trivial the wound may be. Also first aid is immediately extended to every student injured and even trifling abrasion of the skin treated with anticeptics. By means of detailed records of accidents and methods of treatment, the general problem of accident prevention is being carefully studied and analized.

One of the common safety first signs reads "The best safety device is a careful man". There is truth in every word of it.

Safeguards, signs and warnings all play their part in the prevention of accidents but they will not eliminate them. The worker is the only agency that has the power to prevent accidents and a safety first campaign will not become effective until the worker thinks and acts "Safety". A great deal of thought is being given to the developement of this phase of the safety first campaign and in shop laboratories a movement was started this year aimed to accomplish the result so earnestly sought in every plant having accidents from careless workmen in spite of maximum safeguarding and precautions. The average worker is not particularly careful and he is apt to receive injuries regardless of safeguards and warnings. The only method of preventing accidents of this nature is to change the careless worker into a careful worker. It can be done within certain limitations by systematic instruction in safety first principles. The full effect of this training will not be realized for years but eventually it is certain to be just as effective as any other method of instruction.

Besides training the worker in the principles of safety it is essential that he must be charged with the responsibility for application of these principles in his daily work. The workman must realize that he is not only responsiple for his own safety but also for that of his associates. Placing this responsibility on the worker has proved to be a potent factor in the betterment of factory conditions. It was felt that the same policy which has proved so effective in industry would work equally well in the shop laboratories with its large enrollment of students, some of whom were either careless or indifferent. Accordingly plans were developed last summer whereby the responsibility for the conduct of students while engaged in shop laboratory work would be borne by the students themselves. The result was organization of the "Life and Limb" club. This club was to be a student organization having a voluntary membership among those interested in the cause of safety, at least while engaged in shop work. Each of the four shops of the department was to have an independent branch of the club under the supervision of a Chief of Safety. The latter position was filled by the instructional staff by selection from the student body according to prospective merit. In every case the choice was justified and in two particularly so. The Chiefs of Safety were empowered with authority to criticize the methods employed by any student in their respective sections when in their judgement the same appeared dangerous to any individual. They were also directed to point out defects in safety appliances and make suggestions for further betterment. Every member of the club receives a mem-

bership card and button as illustrated in Fig. 3. The latter is worn on the shop clothing in a prominent place as a constant reminder to "Be Careful". Bulletin boards are located in each shop for the display of interetsing safety first information obtained locally and from outside sources. A typical display is shown in Fig. 4.

The results from the operation of the Life and Limb club have been very gratifying but not unexpected. It has been my observation that students will shoulder any amount of responsibility within human limitations and respond intelligent and enthusiastic co-operation in any worth while enterprise connected with their education. The Life and Limb club apparently comes under the latter designation judging by accomplishment for the first semester it has been in existence. During the year 1914-15 students received 28 injuries in the shop laboratories most of which were of a trivial nature (of course every abrasion of the skin may lead to serious consequences). Of these 26 injuries were classed as "avoidable" and were the results of carelessness or indifference. Two were doubtful, both man and safety devices being at fault. In the first semester of 1915-16 a total of five injuries only have occurred, none of which were serious. Four were caused by carelessness and one through lack of a proper safety device. At the present rate the total injuries for the year will be less than half that of the previous year. The remarkable reduction of the unmber of injuries received by students from year to year since the safety first program was inaugurated arouses the hope that the time is coming when accidents will be a rarity. I am proud of the fine record made by the Life and Limb club on its first lap.

CENTRAL STATION OPERATING.

W. L. ABBOTT

The superintendent of a central station power house has three cardinal injunctions laid upon him: (1) Continuity of service, (2) operating economy, (3) maintenance of equipment; and the greatest of these is that the continuity of the service shall not be broken, and to this principle even the shibboleth "Safety First" takes second rank. Other matters, such as expenses, appearance of property, discipline, etc., may be trifled with and the chief will merely get a reprimand suitable to the case, and all will be forgotten if improvements are made; but if a station goes down and out due to some internal cause and all or a part of the service is thereby interrupted for a time, a black mark will be entered in the record against that chief, his organization and his station, which, although it may be forgiven, will be forgotten only with the lapse of long years. And this is as it should be. The value of electric service is measured largely by its dependability.

The merchant whose lights go out on Christmas eve when his store is full of customers, the office building manager whose electric elevators are hung up between floors full of passengers, the foundry man whose power fails when his cupola is full of molten iron, the manufacturer whose force of hundreds of men is rendered idle for a considerable number of hours during the busy season, and a thousand others who are more or less seriously inconvenienced by the interruption of their power will not stop to reflect on what a vital necessity electricity has come to be in our every day affairs. On the contrary, they will each grab for a telephone with the intention of getting the President of the power company or, failing to reach him, the man next lower in rank,—first, to advise that the power is off; second, to demand that it be restored immediately, and third, to say that the service being rendered of late is the worst ever and that this particular interruption is costing the customer so many dollars a minute, every cent of which loss will be charged up to the power company. I say that this is what the customers have in mind doing when they rush for their telephones, but, fortunately or otherwise, there are physical limitations to the number of conversations possible over a single wire at one time, and so the great majority of the customers are unable to "get at the company" during the critical period and are, therefore, obliged to swallow their wrath, thus poisoning their systems against the power company, as the bill collectors and busi-

ness solicitors will be repeatedly reminded. No wonder then that the station crew and station manager will long be made the subject of both silent and voluble censure by those who have to meet customers. "Continuity of service" is, therefore, the corner-stone of the operating creed.

What, then, are the agencies by which this continuity may best be safeguarded? As this is a discussion of operating questions only, we have a right to assume that the station has an equipment of fairly dependable apparatus, and we will only consider what is necessary to keep it going. The answer is almost entirely comprised in the one word "organization," by which I mean the selecting, training, seasoning, and "loyalizing" of the personnel of the operating force; and as the foundation of this system lies in the quality of the men who make up this organization, too great care cannot be exercised in the selection of the raw material. It should not be assumed that to turn away nine out of every ten who present themselves at the gate for employment would be too great a percentage of rejections, and if half of those who were thus carefully selected were dropped within a few months as being unsatisfactory, the few who remained would be all the better for it.

Such a body of men cannot be assembled in a day, and once assembled it requires time and patience to train them; and after that to knit them into a loyal organization, which feels and desires to feel the touch of elbows, requires years of fair dealing, sentiment and psychology; and as an employe in a responsible position during his first year barely earns his wages, to say nothing of the greater expense of seasoning and training him, it is of the greatest importance that the fewest changes possible be made except as necessitated by the growth of the business and to fill the vacancies caused by unavoidable withdrawals. It should, therefore, be assumed that any employes who hold their positions for a year in a large power house are in for life. And to make them remain in the power house they should be made to realize that their positions are secure and that they are in a line of promotion, where their positions are secure during good behavior and where advancement depends only upon their own capabilities and on vacancies further up the line.

But, as is usually the case, only uneducated candidates apply for the laborious, low paid positions at the foot of the ladder, and as the capabilities of these men, with rare exceptions, will permit of their being advanced only a limited way toward the responsible positions near the top of the organization, it is necessary to feed into the line at some place a supply of higher

grade, technically trained material, who will be content to remain in the service and in the line of promotion from the point at which they enter it, and from there work up to fill the higher positions of responsibility.

It is true that a few of those who enter near the bottom and who have not had the advantage of technical training may, by force of character and application, arrive at a point near to or even at the top. This is particularly true of those who have had the equivalent of a high school training, supplemented by night or correspondence school work or by shop experience. But power companies are more and more recognizing the great desirability of having in training in the ranks a number of technical understudies, who can do testing, investigating, and other special work, and who in after years will qualify for the highest engineering positions. To secure such a corps of cadets, as they are sometimes called, some companies have instituted schools for the training of such men, to which are admitted carefully selected technical graduates or promising non-technical men from the organization, who are put through a regular course in practical engineering, extending over one, two or three years, during which time they are not only given their tuition free, but are paid a reasonable living wage during the time of their training.

In a large power house, where there are several distinct lines of work, the ordinary untrained employe entering near the bottom naturally grows up in that line of work which he first enters and seldom acquires experience in other lines; but the cadets are shifted from one position to another and from one line of work to another, so that by the end of the course they are educated technically and trained practically and have an all-round experience such as few could hope to attain in two or three times that length of time. In a body of cadets so trained the company can find material competent to fill any of the responsible staff positions in the station and finally to head the organization, and this too without offending those employes in the regular line of promotion who have worked up from the bottom. One and practically the only serious drawback to this system is that men so trained are often lost to the company because of the higher salaries they can command elsewhere; but even anticipating a high percentage of loss from this cause, the system is coming to be considered not only warrantable but necessary.

A power house, like a battleship, is a-tingle with energy coursing through many channels, and so long as men keep their minds on the things they are doing for perhaps the ten-thousandth time

and so long as materials retain a factor of safety, the hum and the humdrum of the place will not be disturbed; but once let an operator's mind wool-gather while he is engaged in an important operation, or if a tension member fails under corrosion or some safeguard yields under its strain, things will happen in such quick succession that a post-mortem is often necessary to determine the sequence of events. It is in the midst of smoke and fire and din that the value of experience and training shows itself. There is no time to plan a campaign if the continuity of the service is to maintain equipment and perhaps lives saved. The responsible operator or operators must comprehend the situation at a glance and do the right things instantly, usually by involuntary reflex action.

It must not be supposed that the operating efficiency of an organization is to be measured entirely by its skill and promptness in meeting an accident. A far better measure of efficiency is the number of accidents which do not occur, and to prevent such occurrences two things are principally necessary: First, to keep the operators alive to their work, and second, to have a system of inspection which will detect points of weakness where the apparatus is liable to fail and to make prompt repairs before such failures occur.

If "good service" is the corner-stone of the operating, "the organization" is the keystone of the arch, and indeed some authorities say that a well rounded, efficient and loyal organization would require as much time and money to replace as would the power house and its equipment.

Well selected and trained operators are humanly perfect, but are also humanly fallible. They are, therefore, advantageously supplemented by mechanical devices, whose shortcomings, whatsoever they may be, are not of a human sort. On switchboards, for example, switches are made interlocking so far as possible, and indicating instruments are provided to give vital information concerning the condition of circuits and apparatus which are being manipulated; and both as a guide for and a check on the operation of synchronizing an automatic record is made at each operation, showing just how much out of phase the two systems were at the instant the synchronizing switch was closed.

We said in the beginning that the first commandment to the operator is "continuity of service," and the foregoing is a description of some of the means to that end. We will now consider the second commandment, viz., "Operating economy."

The expenditures for operating purposes are, in the order of magnitude, as follows: Coal, labor, supplies,t—the item for coal being far in excess of the other two combined, which fact

at once suggests where lie the greatest possibilities for savings; for example: It is not unusual to find a boiler plant operated so as to yield in the steam generated only 50 per cent of the amount of heat contained in the coal burned, and it might also be possible to operate the same boilers on the same load so as to yield in the steam 75 per cent of the heat in the coal burned. And if the cost of coal is say three-quarters of the entire operating cost, a change from 50 per cent to 75 per cent in the thermal efficiency of the furnace and boiler means of itself a saving of one-quarter of the operating costs. Let us consider for a moment the theory of these losses:—

The potential heat of the coal is utilized by converting it into sensible heat which is soaked up by the air passing through the fuel bed, and which in turn gives the heat up to the boiler surface with which it comes in contact a fraction of a second later, thus serving for the time as a carrier of heat. But as the surface of the boiler is at a temperature higher than that of the air as it enters the fuel bed, it is evident that the air must leave the heating (or cooling) surface and enter the uptake at a temperature higher than it originally had, thereby escaping with a portion of the heat that was intrusted to it to convey to the boiler; and the ratio of the furnace temperature to the uptake temperature is a measure of the boiler and furnace efficiency. And the efficiency will go up as the furnace temperature goes up and the uptake temperature goes down, and the efficiency will go down as the furnace temperature goes down and the uptake temperature goes up. Therefore, the problem is how to maintain the greatest possible difference in temperature between furnace and uptake.

One means to this end is to make easy the transfer of heat between the hot air of the furnace and the hot water of the boiler. There is little difference in temperature between the two sides of the metal of a boiler tube, but if there is a little coating of lime on the inside and a little coating of soot on the outside, the loss of efficiency at once becomes serious. The internal treatment consists in doctoring the water so as to prevent its mud from hardening into a condition which will not permit of being blown out, and the external treatment is merely to blow the soot off the tubes once or twice a day, but what is of even greater importance is to burn the coal with the least possible amount of air.

Of two other principal causes of loss, one is the unburned fuel that is discarded with th eashes; the other is the leakage of air through the brick of the setting, either of which may be considerable, but both combined seldom equal the loss to excess air

through the grate. All of the losses combined cannot well be less than 25 per cent, but may run as high as 50 per cent in an extreme case.

The opportunities for wasting coal are many and great, and unless the boiler room force is selected with a view to including a considerable amount of intelligence, which may be taught and trained, and unless after being carefully selected and instructed it is carefully supervised and proper checks and discipline maintained, the impression will gradually develop that a little coal more or less will not be noticeable where so much is being used, and the standard of the boiler room will drop to some easy going level, where enough coal is wasted to pay the boiler room wages three times over.

It is in the boiler room that the greatest amounts of money are saved or wasted, but in the operation of the new steam turbine and particularly of its condenser there are chances which must not be overlooked. It goes without saying that all parts of the system which carry a pressure less than atmospheric should be carefully inspected for air leaks, as a very little air can raise hob with the vacuum, and an extra inch of vacuum is worth 1 per cent of the fuel.

This conservation of steam by the various means mentioned includes some of the several means of saving coal, the cost of which is the one big item (60 to 80 per cent) of the entire station expense.

Next in importance to coal is the payroll, and as this item is only about 15 per cent of the entire station expense, it is easily possible to be penny wise and proud foolish with it, as a very little more will pay for the difference between intelligence and stupidity, diligence and indolence, loyalty and disloyalty; and when you pass a certain low point, the more the wages are reduced the higher the other expenses go.

The item of supplies is usually a minor one compared with the other expenses, and consists principally of oil waste, janitors' supplies, etc., and while there is a low point beyond which it is not advisable to reduce them, that point should be determined and checks established to detect any increase in these items which would indicate a waste of the material.

The three principal items of operating expenses are coal, labor, and supplies. Watch your labor, and your labor will watch the other two.

We must maintain continuity of service and operate with economy. We must also have a care for the maintenance of the property and keeping it up to a high standard of efficiency.

This will require work from time to time on such pieces of apparatus as are accessible or can be spared from service long enough for such repairs. With large and more needed equipment, hurry-up repairs can often be made during a night or during two nights and the included Sunday, as the day of rest for the people is the day of opportunity for the station repairman.

The season of high loads of a power house is usually during the winter months and particularly during the season of shortest days. With such a load there is an opportunity during the summer to thoroughly inspect and overhaul the larger pieces of the equipment, and this means to dismantle and inspect and to replace any parts which show the effects of severe wear. Not infrequently it means to entirely discard the entire machine and replace it with a new one of the same or of an improved type. In this work it is necessary to maintain a force of competent machinists under an experienced master mechanic; and while this force must be distinct from the operating force, it is occasionally convenient to transfer operating men to the repair gang during periods of light load and also to draw on the repair gang in an emergency for an operating man.

It is generally assumed that anything that looks good is good, and that nothing is good that does not look so. If the appearance of the power house and its equipment is neglected, it is a safe assumption that the mechanical conditions are also being neglected; but if attention is given to such matters as wiping, polishing, painting and janitor work, it is reasonable to suppose that more essential matters are also receiving attention; and if the appearance of the property is allowed to deteriorate, it seems to lower the tone and spirit of the whole force, so that it will be impossible to maintain as high a standard in those matters which have a direct bearing on efficiency. But however well the station is maintained, the day will come and in a surprisingly short time too, when for the continuity of the service and economy of operation the obvious thing to do will be to abandon the property for power house purposes and dispose of the painted and polished apparatus to the junk man at an insignificant fraction of its original cost, for however well designed and however well built and maintained, a little time in these days "makes ancient good uncouth." And the power company, to keep abreast of progress, to conserve its interests, and to live within the rates fixed by public commissions, must prepare to build more noble power houses as the swift seasons roll.

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EDITORIAL

This issue, the second in the series, is devoted to the Electrical Engineering department and to electrical engineering subjects. Rather than have the department and its work written up in a glowing account by some person probably partial, the staff and Professor Paine have devised a different scheme, namely, to let the department speak for itself. Accordingly, this issue of the TECHNOGRAPH is made up of a collection of short articles on the work being done in the E. E. school. The articles speak for themselves and the department as well, so you are left to form your personal opinion of what we think is the best Electrical Engineering school in the country.

NEWS ITEMS

During the short courses, which are given at this time at the University, there have been several exhibits of engineering instruments shown in Engineering Hall. The Bausch and Lomb Co. had a very complete and intersting line of surveying instruments; the Keuffel and Essex Co. displayed the "last words" in slide rules and calculators; the Lufkin Rule Co. exhibited their line of measuring tapes, in various sizes and kinds; and the Eugene Dietzgen Co. showed their great variety of drawing instruments and drawing sets.

Mr. James Mapes Dodge, who has been connected with the Link-Belt Company since its very beginning, and who was Chairman of the Board of that company, died at his home in Philadelphia, last December. Mr. Dodge was one of the pioneers in the Conveying and Elevating art, and his inventive genius was a conspicuous factor in its broad and successful development.

CERAMIC SOCIETY NOTES

A rather small but enthusiastic audience turned out to hear Mr. Danielson's talk on "Cast Iron and Sheet Steel Enamels," at the meeting preceding the Christmas vacation. The speaker had had some experience in the sheet steel enamel working during the summer and a resume of this work, together with a general discussion on metal enamels made up a very interesting dissertation.

On Thursday evening, January 20, the society gave their annual smoker to the short course students. The affair occurred in the banquet hall of the Bradley arcade. Smokes, apples, individual pies, milk, and "toasts" were in vogue. "Dutch" Benner entertained with the cabinet grand. Short talks were made by

various short course students, faculty members and students. Professor Bleininger's talk on "The Union of the Clay Industries" was especially interesting. Some of the notables in ceramic work how were in attendance either at the short course or at the smoker: T. S. Mann, Portland, Oregon; G. C. Hoffman, Mexico, Texas; W. P. Brannon, Dickinson, N. D.; F. A. Morgan, Cleveland, Ohio; C. E. Carter, Peoria, Ill.; L. J. Sheridan, Chicago; R. T. Stull, Conneaut, Ohio; H. F. Staley, Ames, Iowa; C. B. Harrop, Columbus, Ohio.

The society will be represented at a meeting of the State Clayworkers' Association at Peoria, by Messrs. Millsom, Deaver, Lyons, Treischel, and Robertson, who will endeavor to entertain with several stunts pertaining to the industry. The meeting occurs during the first week in February.

Several of the undergraduate members are planning to attend the meetings of the American Ceramic Society at Cleveland, which occur during the latter part of February.

C. C. Treischel.

M. E. SOCIETY NOTES

The M. E. Smoker was held Friday evening, January 14th, in the Y. M. C. A. auditorium. It was a success from all viewpoints. The attendance was very good, talks were good, "eats" were good, music was good, everything was good.

The music for the evening was furnished by Owens, violinist; a stronge trio, composed of Pfieffer, Becker, and Clark; and a quartet of M. E's. All were brought back for encores. The quartet led the audience in "I'm a Rambling Wreck, from Illinois Tech, a Mechanical Engineer," the M. E. song.

Speakers for the evening were President VandenBoom, Professors Leutwiler, and Goodenough, and Mr. DeTurk. Mr. Krons, engineer for the State Public Utilities Commission, gave a short talk in which he lamented the fact that the engineer is not highly paid or protected in his position.

Following the speeches the lucky ticket contest was held. R. N. Foster, a sophomore, was the winner. The prize was a handsome copy of Professor Goodenough's Steam Tables.

A smoke and eat fest followed. Every M. E. received liberal lunch, all the cider he desired, and the "smokes" which consisted of pipe, tobacco, and cigarettes. The whole evening's program lasted about two and one half hours. Everyone was pleased with the smoker.

On the evening preceding the smoker, January 13, Mr. O. Monett of the American Boiler & Radiator Company lectured before the Society on "Boilers and Boiler Settings for Smoke-

less Combustion." Mr. Monett was well qualified to talk on that subject, having served as smoke nuisance inspector in Chicago.

He treated the subject from the ground floor up, showed the effect of smoke on vegetation, and animal life, explained the manner in which sulphuric acid is formed in the air by the sulphur gases emitted from the coal. This led to the discussion of different types of boilers and their arrangement for proper combustion of the volatile gases which cause smoke. Many lantern slides were used in this part of the lecture. The speaker treated this subject from an impartial viewpoint, giving more credit to the proper setting up of the boilers than to the maker of the particular boiler.

He also showed how locomotive smoke could be almost eliminated by the proper building of the fire. Lantern slides showed the remarkable effect of a new system of fire-building in use in the shops of large eastern railways.

The lecture was both interesting and instructive and was one of the best lectures given before the society in the past year.

On January 20th, the Society heard a talk by Mr. W. A. Bloneck of Bloneck and Co., Engineers, of Chicago. Mr. Bloneck showed, by lantern slides, the ways in which European engineers are able to operate boilers at a much greater efficiency than American engineers. The limited fuel supply of European countries makes high efficiency necessary. Mr. Bloneck says that the sooner America learns to economize on her fuel supply the better, for our coal supply is rapidly being consumed under our present wasteful practices.

On December 16th a business meeting of the Society was held. Routine business was carried on. President VandenBoom urged the members to attend the lectures better. A committee was appointed to arrange for the M. E. smoker. The membership of the Society was given a "boost" at this meeting.

The destruction in the Co-Op fire of the cup offered by the Professors of the M. E. Dep. does not put a stop to the contest. A new cup will be purchased for the winner of the contest. The man who wins the cup will have a handsome prize. But every man who enters the contest will profit by the experience, in speaking and in preparing finished reports. Get into the contest M. E.

V. S. Day.

C. E. NOTES

On December 7, 1915, Mr. Keuffel of the Keuffel and Esser Co. gave a short talk to the C. E.'s on the construction of the transit. Mr. Keuffel brought along several models, one of which

he took to pieces, explaining, meanwhile, the process of manufacture and the purpose of each piece. It would, perhaps, not be out of place to note here how such high degrees of accuracy, as are required in a transit, are secured in the manufacture of the instrument.

For graduating the limb, a very accurate, automatic, electrically driven dividing engine, which is kept in a room of constant temperature is used. After placing the limb in the machine, the operator goes to the opposite end of the room, in order that the heat of his body should not affect the device, and turns on the power. By taking these precautions, the engine is accurate to within one or two seconds.

The centers are turned almost to size in a "dead center" lathe. In this lathe, the spindles are stationary and the work is turned from an independent source. Thus the work becomes its own center and is turned absolutely true and symmetrical with respect to its own axis. The centers are then ground together by hand, using oil and pummice and, later, without any abrasive. A fit so tight that there is no room for a film of oil, is thus secured.

In the telescope tube are two collars upon which the objective and eyepiece tubes rest. The collars are turned on a lathe built upon the same principles as the dead center lathe, are also turned true and symmetrical, and are finished, in this lathe, to within one-fifty-thousandth of an inch.

After being postponed twice, the C.E. meeting originally scheduled for Nov. 18 was held Dec. 10, in Engineering Hall. At this time the following faculty members were elected to honorary membership: Dr. F. H. Newell; Mr. H. E. Babbitt; Mr. R. E. Davis; Prof. C. A. Ellis; Prof. A. B. McDaniel; Mr. W. H. Rayner; Mr. J. E. Smith; and Prof. W. M. Wilson.

At this meeting Mr. F. C. Norlin spoke of some of his experiences as an inspector on government dredging work. Mr. Norlin spoke first of the size and capacity of dredges and scows used on the jobs on which he was inspector, then of the methods used to prevent dredging over the same groun dtwice, of the methods used to prevent undermining of docks, of specifications for dumping waste material, and of the amount of money spent annually for dredging purposes by the government.

Mr. Norlin also explained some of the clever graphical methods which he devised and used to determine the efficiency of the dredges, and location of dredges for excavations near docks. At the end of his most interesting lecture, Mr. Norlin passed out samples of government inspector's reports, tables of scow

capacities and tables for determining volume reductions for partially filled scows.

The C. E. Club picture was taken on the front stairs of Engineering Hall at noon, Dec. 8.

W. A. Himmelreicher.

ELECTRICAL ENGINE ERING DEPARTMENT NOTES.

The Electrical Engineering Department and its research work have brought to the notice of the industry thru the following article in "The Electrical World" of January 15, 1916:

"Trygve D. Yensen, whose production of vacuum-fused iron having a permeability four or five times that of the best magnetic iron or iron-alloy heretofore produced, has attracted wide attention in the scientific and industrial fields, has, in recognition of this work, just been appointed research assistant professor of electrical engineering at the University of Illinois, Urbana. Mr. Yensen was born in Christiain, Norway, in 1884, and was graduated from the University of Illinois in 1907, taking an M.S. degree in 1912 and an E.E. degree in 1913. In 1907 his theseis for his B.S. degree won him the Edison Medal of the A. I. E. E. Following graduation he served for a time in the testing department of the General Electric Company and later became assistant engineer of the Shawinigan Water & Power Company of Montreal, Canada. Iron of extreme chemical purity and remarkable magnetic properties has been produced by Mr. Yensen by melting electrolytically refined iron in an electric furnace in a vacuum, thus preventing contamination by surrounding gases during the melting process. The maximum of magnetic permeability of this iron was found to be about 20,000, which is two or three times as high as that for the best magnetic iron or alloy. Later, by alloying the vacuum-fused iron with silicon, the maximum permeability was raised to above 50,000. Meanwhile the hystersis losses of the silicon-iron alloys have been found to be from one-fifth to one-twentieth of the corresponding losses for ordinary grades of iron.

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The Technograph

Vol. XXX April, 1916 No. 3.

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Engineering Hall

The Technograph

Vol. XXX April, 1916 No. 3

ARE THERE OPPORTUNITIES FOR COLLEGE GRADUATES IN RAILROAD WORK?

BY W. H. HAUSER

Mechanical Engineer, C. & E. I. R. R.

What are the opportunities for college graduates in the railroad field? Have college graduates an equal chance with the self-educated or self-made man who has spent all his life in railroad work? What can the college graduate do to succeed in the great railroad field?

To find people who are unfamiliar with at least the outward appearance of the American railroad, one would have to go to the very smallest town or hamlet. Everyone knows railroad men. They have at least seen and talked to the conductors, the enginemen and the ticket agents. In the typical railroad town, where railroads have large shop or terminal facilities, the railroad men often dominate the social life and the business interests. Their years of abundance are the years of abundance for the town, just as their lean years are the town's lean years.

The railroad, however, is so complex that very few of those who use it understand or appreciate the complexity of its organization. To the average citizen, a railroad on the prairie looks like a simple, easily constructed and easily managed unit. On the other hand, the railroad through the mountains or over rivers appears to be a very hazardous undertaking. As seen in a large city or in its offices or shops, the railroad looks like the most complex organization imaginable. The highly efficient American railroad is divided into many simple and many complex divisions and departments, which often are so different from each other as is the clothing store from the village blacksmith.

The field of railroad work has broadened greatly in recent years. In response to that growth, our great State Universities have organized railway departments where special attention is given to the development of men who wish to enter these various railway fields. It is to be expected that these young men have worked out some sort of plan that they intend to follow in their life of railroad service. Some of them are well versed in an understanding of railroad organization. They may have been

raised in a railroad family or they may have lived in a town or city where the railroad life dominated. But also there may be instances where the young men entering or leaving college have not definitely analyzed their future. They know that railroads have paymasters, traffic managers, superintendents, superintendents of motive power, chief engineers, general managers, and presidents. But just how the men who are filling these positions were able to win them, or what it means to have and to hold one of these positions, is not very definitely settled in their minds. They are not sure whether the railroad executives are old or young men, whether they began railroad work when very young, whether they just happened to drop into a position, whether they were graduated from a college, or whether they were self-made and self-educated. There are, and must be, many questions which men in college, and especially those ready to graduate, ask themselves. These questions should be answered, and a definite plan should be laid out so that men fitted in college for some special work may know best how to follow and succeed in that work.

Corporations, manufacturing concerns, railroads, and all large business ventures, have definite organization schemes. If one understands these schemes thoroughly, he can analyze them in a broad manner and see how and in what manner a college graduate may enter such a service; and, providing he finds himself suitable for the work he has chosen, how he may advance step by step through various departments to the ultimate goal he is seeking. The field of railroad work is as broad, and offers as many opportunities to college men, as any other field. This is so, I believe, irrespective of the branch or department of railroad work chosen. Advancement and success depend entirely on the man. There will be periods of discouragement. There may be temporary retarding of advancement. But this can be overcome, and if a man is anxious and eager to succeed, if he is willing to work hard, such barriers will only serve to spur him on to greater effort and to final success.

The ground plan or foundation laid by the college graduate in the first years after graduation, marks the critical period of his life. Some people call a college education a man's foundation, and advise him to build it well and strong. I am inclined to call a college education *not* the foundation, but the *excavation for the foundation*. It might be said that the foundation is laid during the first few years of actual apprenticeship after leaving college. Does the college teach a man how to do the actual deeds of life? Too frequently college men do not seem to appreciate the necessity of starting at the bottom after graduation.

Too often they appear to feel that their education relieves them of learning the routine part of their work. In reality, an apprenticeship must be served in order to achieve the success all are aiming at.

Are there opportunities for college graduates in railroad work? The answer can only be, "Yes". The civil engineering department of all railroads is now largely made up of college men from the newest chainman to the chief engineer. The test and chemical departments on all roads are almost entirely made up of college men. There are college men scattered through all of the other departments.

The department organization lends itself readily to the employment of college men and to their ultimate success. In order to illustrate this organiation more clearly, the table following shows how the authority or power necessary to manage our great railroad system is delegated:

By this table one can readily trace the many channels of advancement for those college men who enter the railroad field. The civil engineer, if he has never had any railroad experience, should start as a section laborer, working with shovel and pick, then section foreman, supervisor, assistant bridge and building foreman, level man, assistant, either in the office or the field, to the division engineer, and then division engineer. The graduate entering the operating departmen, has many lines or fields to start in. You will find division superintendents who have started as telegraph operators, brakemen, switchmen, call boys, baggage agents, station agents, section laborers, firemen, machinists, and so on. There is perhaps no branch of railroad work where greater diversity of original employment can be found. You will find also that the men holding the division superintendents' positions are always keen, well-informed men; clearly demonstrating that college-educated men are the very men who are wanted in such positions. But the competition will be keen. The college man entering any of the minor positions will find himself surrounded by men who have had much experience in all phases of their work, and, while in most cases these men are not college educated, they are self-educated, and are very worthy opponents and rivals in the race for advancement and success.

The chart shows also how other departments besides the operating department, are organized. Many of these departments are highly specialized, such as the legal and financial departments, where are found many college men. Then there is the auditing department, with its many trained accountants; the purchasing department, where general and accurate knowledge

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PRESIDENT
VICE PRESIDENT IN CHARGE OF PURCHASES
PURCHASING AGENT
ASSISTANT VICE PRESIDENT
CHIEF CLERK
OFFICE CLERKS
ASSISTANT PURCHASING AGENT
STOREKEEPERS
OFFICE CLERKS
GENERAL STOREKEEPERS
DISTRICT STOREKEEPERS
TERMINAL STOREKEEPERS
DIVISION STOREKEEPERS
LOCAL STOREKEEPERS
SCRAP FOREMAN
OIL MEN
STORE CLERKS
FUEL STOREKEEPERS
COALING
FUEL INSPECTOR
VICE PRESIDENT IN CHARGE OF LAW AND LEGISLATION
SECRETARY
ASSISTANTS
LAND COMMISSIONER
GENERAL COUNCIL
GENERAL SOLICITOR
GENERAL ATTORNEY
CLAIM AGENT
ASSISTANT
PALMASTERS
TREASURER
COMPTROLLER
GENERAL AUDITOR
ASST. GEN AUDITOR
AUDITOR OF DISBURSEMENTS
AUDITOR OF PASS ACCTS
FRT. CLAIM AUDITOR
TRAFFIC AUDITOR
VICE PRESIDENT IN CHARGE OF OPERATION
ASSISTANTS TO VICE PRES.
GENERAL MANAGER
SUPT. OF TELEGRAPH
SUPT. OF TRANSPORTATION
CAR ACCOUNTANT
GEN. INSP. TRANSPORTATION
GEN. CLAIM AGENT
ASST GEN CLAIM AGT.
FREIGHT CLAIM AGT.
ASSISTANT
ASSISTANT TO PRESIDENT
VICE PRESIDENT IN CHARGE OF TRAFFIC
GENERAL PASSENGER AGENT
ASST. GEN PASS AGT.
PASS. TRAFFIC MGR.
GENERAL BAGGAGE AGT.
ASSISTANTS
MGR. FOREIGN PASS. SERVICE
ASST. FRT. TRAFFIC MGR.
GEN. FRT AGENTS
FREIGHT TRAFFIC MGR.
GENERAL FREIGHT AGENT
ASST. GEN FRT AGTS.
TRAVELLING FRT AGTS.
CHIEF ENGINEER
SUPT. OF MOTIVE POWER
(SEE FIG II)
GENERAL SUPERINTENDENT
CHIEF CLERKS
OFFICE CLERKS
DIVISION ENGINEERS
BRIDGE ENGINEERS
WATER SUPT. ENGINEERS
OFFICE ENGINEERS
SIGNAL ENGINEERS
PER. TIMEKEEPER
SIGNAL SUPERVISOR
SIGNAL FOREMEN
ASSISTANTS
ROAD MASTER
SECTION FOREMEN
CHIEF CLERKS
CLERKS
TERMINAL SUPT.
DIVISION SUPT.
AGENTS
TRAIN MASTERS
TRAIN MEN
BAGGAGE MEN
PASS. AND FREIGHT AGTS
FREIGHT AGENTS
CHIEF CLERK
CHIEF DISPATCHER
DISPATCHERS & ASSISTANTS (CROSSING)
TELEGRAPH OPERATORS
OFFICE CLERKS
TIME KEEPERS
ASSISTANTS

of the many materials used and purchased is necessary; the traffic department, which originates new business, holds old business, and in which a successful career requires the keenest and brightest mind.

Then in addition to all of these different departments there is the mechanical department, which cares for the maintenance of cars and locomotives. This department seems to be the one department which has not been favored by college men as it should have been, considering the opportunities it offers. Of course there are some college men in this department, but not in proportion to the number found in the teaching profession, in the legal profession, and in many other fields. The work of the mechanical department is broad, and the opportunities are as great, if not greater, than many other lines of work. Perhaps the deficiency is due to the lack of a thorough understanding of that particular department.

The mechanical department of the average railroad is often spoken of as a hard taskmaster. It requires that anyone entering its service, who intends to adhere to the regular lines of advancement which it offers, must serve an apprenticeship in the shop of three or four years; then continue in the shop, studying, analyzing and absorbing the many items of mechanical knowledge connected with a locomotive or car until experience has broadened him for a foremanship, or for other special advancement. There is almost absolutely no road to ultimate success in the mechanical department of a railroad unless a man will serve his apprenticeship and learn the ground-plan of a mechanical department railroad operation. The subjects to be learned are so complex there can be no other way. The multitude of men the college man finds at work in the shop contains so many self-educated, keen men that have this practical knowledge, that in order to compete with them on an equal basis, college men must learn what they have learned. He must absorb what they have absorbed. He must live through their experiences, that he may deal intelligently with these experiences as they arise again and again. It probably will be said that this is true in all walks of life; but to the man entering the mechanical department of railroad work, it must be taken almost as a religion. Ultimate success for such a man can be said to rest entirely on the first apprenticeship.

Below is shown an organization diagram of the mechanical department of a typical American railroad.

The man in central authority is the general superintendent of motive power. The man in lowest order is the college graduate who has just reported for work as a special machinist apprentice.

GEN. SUPT. MOTIVE POWER
SUPT. MOTIVE POWER
MASTER CAR BUILDER
GEN. BOILER INSPECTOR
GEN. PAINTER FOREMAN
STORE KEEPER FOREMAN
MACHINE FOREMAN
BLACKSMITH FOREMAN
PIPE FITTER FOREMAN
WHEEL FOREMAN
PAINTER FOREMAN
ASSISTANTS
TRANSPORTATION INSPECTORS
GEN. PASSENGER FOREMAN
CLERK FOREMAN
TRAIN FOREMAN
YARD FOREMAN
PIPE FOREMAN
INSPECTORS
DIVISION MASTER MECHANIC
ROAD FOREMEN ENGINES
ROAD FOREMEN CARS
GENERAL FOREMAN
ROUND HOUSE FOREMAN
BOILER FOREMAN
BLACKSMITH HELPERS
TINSMITHS
MECHANICAL ENGINEER
PATTERN FOREMEN
CHIEF CLERK
CAR FOREMAN
INSPECTORS
CHIEF DRAFTING ROOM ASSISTANTS
CHIEF DRAUGHTSMAN OF CARS
STATIONARY PLANT FOREMAN
DRAFTSMEN
TRACER
BLUE PRINT BOY
BOILER ROOM MEN
ASSISTANTS
LABORERS
PAINTERS
MACHINIST HELPERS
DRAFTSMEN
COMPUTERS
ELECTRICIAN FOREMAN
ENGINEER OF SHOP CONST.
ELECTRICAL ENGINEER
OFFICE ASSISTANT
ASST. IN CHARGE OF SET-UP
OFFICE ASSISTANT
DIVISION ACCOUNTANT
SHOP ASSISTANT
ARC LIGHT ENGINEER
GEN. AIR BRAKE INSP.
OFFICE CLERKS
TIMEKEEPERS AND CLERKS
INSPECTORS CLERKS
ENGINEER OF TESTS
MATERIAL INSPECTOR
TRAVELLING ASSISTANTS
OFFICE ASSISTANTS
LABORATORY ASSISTANTS
COMPUTER
CHEMIST'S ASSISTANTS
METER ANALYSTS
LABORATORY ANALYSTS
SHOP SUPERINTENDENT
CHAIRMEN OF BOARD POINT
OFFICE ASSISTANTS
PLANT TESTS AND SURVEYS
ENGINEER
GEN. PIECE WORK INSPECTOR
DIVISION ACCOUNTANT
STOREKEEPERS
OFFICE FORCE
SUPERVISOR OF APPRENTICES
SHOP INSTRUCTORS
SCHOOL INSTRUCTORS
BLACKSMITH FOREMAN
BOILER FOREMAN
PIPE AND TIN FOREMEN
GENERAL FOREMAN
ERECTING FOREMEN
MACHINISTS HELPERS
MACHINE FOREMEN
MACHINIST MEN
TOOL ROOM FOREMAN
CHIEF CLERK
OFFICE CLERKS
ASSISTANT FOREMAN
BOILERMAKERS HELPERS
TENDER FOREMAN
TANK MEN

Let us take such a man for example. He enters a large shop and for three or four years works and learns the rudiments of the machinist trade. He operates machines, aids in stripping down and erecting locomotives, lays out and plans difficult jobs which appear frequently in a large locomotive shop. He has special knowledge which the ordinary apprentice and even often mechanics have not, and is therefore used on special work about the plant, such as sketching, drawing, difficult laying out, miscellaneous shop testing, requiring special attention and road work on locomotives and cars. He acts as temporary foreman on various occasions. In short, his work is interesting and constantly educational, and at the close of his apprenticeship he will have a very good general and technical knowledge of his department. His wages, it is true, have been low; but when he completes his apprenticeship, he immediately can command a minimum wage equal to that of a mechanic. He has a trade, and his minimum in the future will be that trade's minimum.

After he completes his apprenticeship he will have many different offers. He can enter the test department, the mechanical engineer's office, the piece-work or bonus department, the power plant engineer's office, the apprentice educational system, or some other special department; or he can remain in the operating mechanical section of the road. If he chooses the latter he should soon be a foreman. Then, if he has developed step by step, to general shop foreman, shop superintendent or general round-house foreman, master mechanic and superintendent of motive power.

All of these opportunities are his if he is willing to serve his shop apprenticeship and compete with his fellows on their ground. If he does this, and enters some special department after he has served his apprenticeship, he has great advantages over the college man who entered the special work as a specialist. A college man may enter as a test department specialist or as a draftsman in the mechanical engineer's office, and succeed. He may become an engineer of tests or a mechanical engineer, but as many roads do not have either of such positions, and none have more than one of each, his opportunities are much greater in the operating end of the mechanical department, where large roads have many different general foremen, master mechanics, etc.

Railroad mechanical work is an interesting and enjoyable work. The instruction and knowledge one obtains is helpful in other business fields. Everywhere one investigates among mechanical supplysalesman, he will find railroad men who are successful and who are known as leaders in their special line. Many managers and presidents of large manufacturing concerns are former rail-

road men. In fact, one can seldom find a large plant or corporation that has not its full quota of railroad men. The majority of them have come up through the apprentice or shop-foremanship line of promotion. They know their business thoroughly, and they hold positions that college graduates can honestly and heartily covet. They are leaders in their business and are well received in the social world.

More graduates of the engineering colleges should enter the mechanical department of our railroads. The opportunities are real and inviting. The work offers a wonderful field for technically educated men. As soon as college men appreciate these opportunities there is no question but that they will realize what great opportunities have been overlooked.

INTERNATIONAL ENGINEERING CONGRESS, 1915

SAN FRANCISCO, CALIF., U. S. A.

The Committee of Management, International Engineering Congress, 1915, announces that the volume on Mechanical Engineering is ready for distribution and the members who have subscribed to this volume will soon receive it.

The other volumes will be issued as rapidly as possible. Owing to the large amount of material to be reprinted, and the thousands of copies to be bound, the work cannot be carried on with greater speed. However, it is hoped that within two months the entire set will be completed.

Members who did not send in their final selections may be disappointed in not securing all the volumes they might have had in mind, and at this date the Committee has decided to close the lists for certain volumes which have been sent to the press. It may be possible to supply members who would apply at this late hour with copies of volumes which have not gone to press.

W. A. CATTELL, Secretary, 425 Foxcroft Building,
San Francisco, California, U. S. A.

THE ATTITUDE OF THE PUBLIC TOWARD ELECTRIC RAILWAYS

BY C. E. EVELETH

Commercial Engineer Railway Equipment, General Electric Company

That good relationships should exist between the public and those conducting the affairs of our public utilities is essential—if the best and most economical results are to be obtained. To help bring about good relationships the American Electric Railway Association has adopted a "Code of Principles", which we publish in this article. This code has special value as representing the carefully considered work of those representing the public utilities.—EDITOR.

REPRINT FROM GENERAL ELECTRIC REVIEW

It is of vital importance to all of us who have at heart the best interests of the communities in which we live that every industry tending to promote public welfare, make living conditions better, and improve values of property and business, should receive intelligent support. The electric railways of the country, with all they have done in these directions, certainly deserve commendation and any assistance that can be rendered.

How prone we are to sit back when our local railway is being knocked by some unthinking individual who perhaps does not appreciate the existing conditions with which the railway management is confronted. This is not right. A few remarks outlining what the electric railways have accomplished, the difficulties—financial and physical—under which they work, and the ever present frailty of the human element, a word of commendation regarding the way the service was restored after some recent storm, would help to set things right and give the thoughtless critic something to consider.

Once in a while it does no harm to shake ourselves together and take a fresh start, especially in any matter which involves public duty or personal inconvenience. We need to do this to get out of the practice of the little girl's father in the trite old story. She was asked if her father was a Christian. "Yes," she said, rather dubiously, "he is, but he isn't doing much at it."

The American Electric Railway Association has adopted a Code of Principles to which we can all subscribe. The code follows and is published anew that we may all do something "at it," say something to make the critics think, labor with our friends in the Common Council, explain the conditions, limitations and needs on every occasion that presents itself, most particularly at every contact with legislators and public officials. A clear understanding by everyone is all that is required to bring about satisfactory conditions to both the public and the companies.

CODE OF PRINCIPLES

(1) The first obligation of public utilities engaged in transportation is service to the public.

The first essential of service is safety.

Quality of service must primarily depend upon the money received in fares. For this reason it is necessary that the rate of fare should be sufficient to permit the companies to meet the reasonable demands of patrons and to yield a fair return on a fair capitalization.

(2) Regulated private ownership and operation of electric railways is more conducive to good service and the public welfare than government ownership and operation because the latter are incompatible with administrative initiative, economy and efficiency, and with the proper development of cities through the extension of transportation lines. The interests of the public are fully protected by the authority given to regulatory bodies.

(3) In the interest of the public and good service local transportation should be a monopoly and should be subject to regulation and protection by the state rather than by local authorities.

(4) Short-term franchises are detrimental to civic welfare and growth because they ultimately check the extension facilities and discourage good service.

(5) In order to render good service, electric railways must be allowed to earn a fair return on a fair capitalization, and the foundation for this result will be obtained, if the issuance and sale of securities representing such fair capitalization shall be legally authorized on such terms as will produce the requisite funds.

(6) Securities which have been issued in accordance with the law as it has been interpreted in the past should be valid obligations on which an electric railway is entitled to a fair return.

(7) The relation of adequate wages to efficient operation should always be recognized, bue electric railways, being public servants regulated by public authorities, should be protected against excessive demands of labor and strikes.

(8) The principle of ownership of securities of local companies by centralized holding companies is economically sound for the reason that the securities of the latter have protection against the varying business conditions of a single locality or company and because money for construction and improvements can thus be more readily obtained.

(9) In the appraisal of an electric railway for the purpose of determining reasonable rates, all methods of valuation should have due consideration.

(10) Full and frank publicity should be the policy of all transportation companies to the end that proper information may be available to the investor and the public.

The following recommendations concerning the establishment of a Bureau of Public Relations are worthy of note:

Publicity and Educational Plans

We recommend the establishment under the auspices of the American Electric Railway Association of a Bureau of Public Relations.

This Bureau to have a competent Director with the necessary assisting employees. The work of the Bureau to be under the general supervision and direction of the Committee on Public Relations of the American Electric Railway Association, with the power in that committee to appoint, either from its own membership or outside, Sub-advisory Committees, who will co-operate in the work of the Bureau.

The Committee on Public Relations to appoint the Director of the Bureau and his employees and to fix their compensation; also, so far as practicable, to make up in advance the budget of the Bureau's expenditures.

The work of the Bureau to be along the lines suggested from time to time by the Committee on Public Relations and to cover particularly the following:

I

The dissemination of information and literature on subjects of general importance to Public Service Corporations, including particularly:

(a) Relations with employees.
(b) Public relations.
(c) Regulatory laws and commissions.
(d) Publicity concerning facilities, service and accounts.
(e) Rate making.
(f) Depreciation and reserve accounts.
(g) Taxation.
(h) Franchises.

The above contemplates close association between the Bureau and Member Companies of the Association as to the furnishing and distribution of reports, information and statistics, and it is suggested that each Member Company be requested to designate a representative through whom correspondence with the Bureau may be conducted.

II

Co-operation with similar committees of other Public Service Associations.

III

Influencing the sources of Public Education, particularly by:

(a) Lectures on the Chautauqua circuits.

(b) Formation of a committee of prominent technical educators to promote the formulation and teaching of correct principles and public service questions in technical and economic departments of American colleges through courses of lectures and otherwise.

(c) Formation of a similar committee in each of the great technical societies, such as the electrical engineers, mechanical engineers, civil engineers, chemists, hydraulic engineers, telephone engineers.

(d) Formation of a similar committee to work in connection with the various civic and economic societies.

(e) Discussions at institutions of learning and Y. M. C. A.'s on subjects pertaining to the relations between the public and service corporations.

IV

The publication in magazines and periodicals of signed popular articles on public service questions by prominent workers in the electric railway industry.

V

Newspaper advertising when desirable and financially possible.

In order to provide the necessary funds for carrying on this work it will be necessary to raise a sum of money, to be subscribed and paid in installments as called for by the committee. All moneys to be expended under the direction and upon the authority of the committee.

Obviously the ability to carry out the extensive program here outlined will depend upon the raising of sufficient money and the wise expenditure thereof. Your committee believes that much of the work outlined can be accomplished through the assistance of Advisory Committees and at comparatively little expense. Even if the funds available should not permit the carrying out of the full program, much good may be accomplished if only certain phases of the work are undertaken. Your committee has enumerated advertising as one field of work and believes in the effectiveness of this method of reaching the public, but it is convinced, after careful consideration, that to carry on any comprehensive program of advertising would involve the employment of more money than can probably be raised, and it therefore recommends the use of advertising only for specific purposes and on special occasions where conditions would seem to justify the expenditure.

RAILWAY ORGANIZATION AND MAINTENANCE OF WAY

BY D. B. OHRUM, '17

The railways constitute in themselves the biggest single business in the country. With an average revenue of over $3,000-000,000.00 and a capitalized value of $15,500,000,000.00, they are larger than any two other single industries combined. In the year 1910 approximately 1,815,000 persons were required to maintain and operate the railways and 750,000 persons were employed in manufacturing supplies for them. Using these figures as a basis it is seen that one in twenty of the population is dependent upon the railways for support. Of more interest to college men is the fact that from 15 to 20 per cent of the engineering graduates are continually in the employ of railways and allied companies.

On June 30, 1914, considering all tracks, a total of 384,000 miles of track were being operated in the United States. In order to better realize the vast mileage which this represents, it can be stated in terms of the circumference of the earth. This track mileage would girdle the earth seventeen times. The distance from the moon to earth is 239,000 miles and the railway mileage is almost twice that distance. The railway (main line) mileage of Europe is approximately 200,000 miles, while that of the entire world is 650,000 miles. Of this amount, the United States has 250,000 miles, or 25 per cent more than the European mileage, and 31 per cent of the entire mileage of the world.

The work of keeping these traks, and the accompanying structures in repair, is called "Maintenance of Way and Structures". The Maintenance of Way Department has charge of the entire fixed property of the railway, or, as it is called in England, the Permanent Way. An idea of the size of this Department can be gained from the fact that one-third of the railway employees are in Maintenance of Way work, and approximately 20 per cent of the operating expense goes for the same purpose.

To within the last fifteen or twenty years, construction played a very large part in railway work. As construction gave way to maintenance work, the construction men were naturally taken into the maintenance department. As a result of this, there has been evolved on the American railway, the so-called "practical railroad man"; the Roadmaster, who has perhaps come up from the ranks with a better knowledge of the art of swearing than

of the science of track. But this type of man is rapidly disappearing from the up-to-date road, his place being taken by men with some technical training along engineering lines, combined with a practical knowledge of track work. This is the opportunity which is being offered to the college man; some roads, notably the Pennsylvania, hiring only college men in the engineering department. The opportunities in this field are constantly increasing with the growing complexity of the work.

In any undertaking requiring the services of a number of persons, the best results and greatest economy in operation can be obtained only by organizing and co-ordinating the efforts of the various individuals. This direction of the efforts of the several individuals to a common purpose is the object of organization. As a firm grows and expands, both in number of employees and extent of territory covered, the more complex becomes the organization.

There are several basic principles which should be embodied in any successful type of organization. They might be stated as follows:

1. At all points where action or decision must be taken, centralize authority in one person.
2. Definitely outline the authority and responsibility of each position.
3. The duties of each position must be made to conform to the capabilities of the incumbent.
4. One person should not be made subordinate to two or more others, especially in regard to matters closely related.
5. The disciplinary authority should be placed in the same hands as the responsibility.
6. The work of administration should be distributed in such a way as to avoid unequal loading of the different officers.
7. There should be no positions which do not permit of promotion therefrom.

If any organization is to be successful and self-perpetuating, some provision must be made for education of employees. They must be trained in the proper performance of their present duties, and be made capable of occupying more responsible positions when promotion comes. In the past, too little attention has been given to this matter, with the result, that, at present many corporations are finding great difficulty in properly filling some of their responsible positions with men of the necessary training and experience. As a result of this condition, more and more attention is being given to the various methods of apprenticeship.

Railway organization is especially complex, due to the diversity of the work to be done and the extent of territory covered.

This has resulted in the formation of several departments to carry on the various features of the work. In some form or another they are in existence on every large road. They are:

1. Legal Department, which gives advice and takes action in legal matters.

2. Financial Department, consisting of the Treasury and Accounting Departments, who receive and disburse money, and keep the accounts.

3. Traffic Department, which procures and develops freight and passenger traffic, and makes rates.

4. Transportation Department, which receives the freight and passengers, and moves them on trains.

5. Mechanical Department, maintaining locomotives, cars, shops, and round-houses.

6. Maintenance of Way Department, having charge of the roadway, track, bridges, etc.

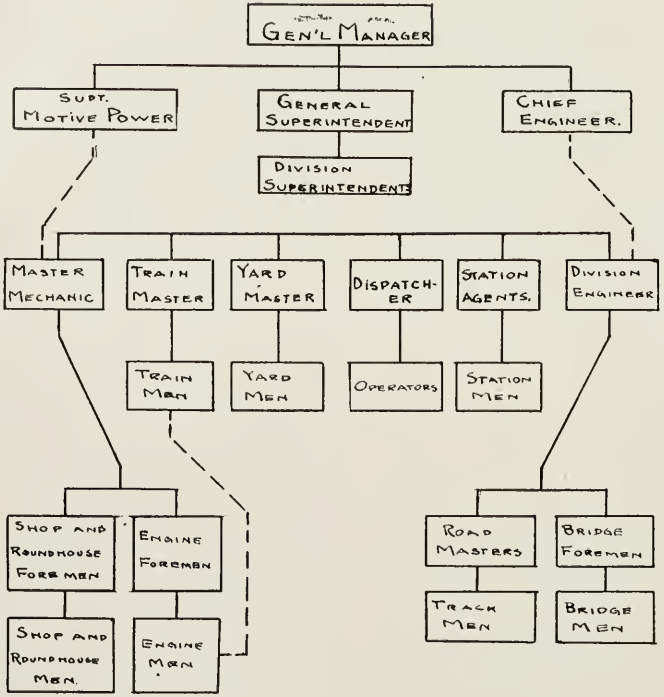
7. Purchasing Department.

In addition to these departments there are other minor ones which may be found on various roads.

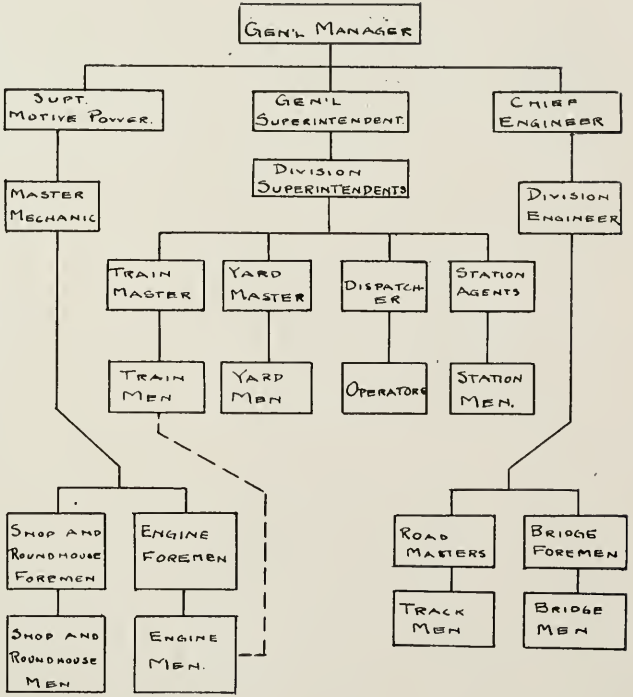
In combining these various departments there has been evolved two distinct types of railway organiaztion, the Departmental and the Divisional, each having certain advantages and disadvantages. The Departmental has been the type prevalent on the continent, while the Divisional has been more commonly used in the United States. In addition to these two, the "Hine" or unit system (an adaptation of the Divisional type) has been tried on several of the American roads, notably the Southern Pacific and the Canadian Pacific. The distinctions between the several types are of relatively small importance on a small road; an on a large road arise only in the Operating Department, consisting of the Transportation, Mechanical, and Maintenance of Way Departments.

The Divisional type more nearly corresponds to a military organization, the road being subdivided territorially, and each division being made an operating unit. Divisional organization attempts to correlate the functions of the Transportation, Engineering, and Motive Power Departments in all matters directly affecting operation and current maintenance, while leaving the Engineering and Motive Power Departments untrammelled in the various technical duties which do not immediately affect the Transportation Department. Or referring to a military organization, it differentiates between so-called staff duties and line duties.

On the other hand, the Departmental type attempts to have each transaction passed upon by an expert at headquarters. On



DIVISIONAL



DEPARTMENTAL.

a road of any extent this leads to confusion and delay, and as a result, the American railways have adopted almost exclusively the Divisional system.

The Unit system, installed on the Union and Southern Pacific by Major Hine, under the direction of Mr. Harriman, and later on the Canadian Pacific, may be regarded as an intensification of the Divisional type, the essential features being that all distinctive titles are done away with, the various officers on the Division being given the title of Assistant Superintendent. In this way the faults arising from a Departmental organization on each dvision are done away with, the men giving more attention to the operation of the road as a whole, instead of to their own particular department.

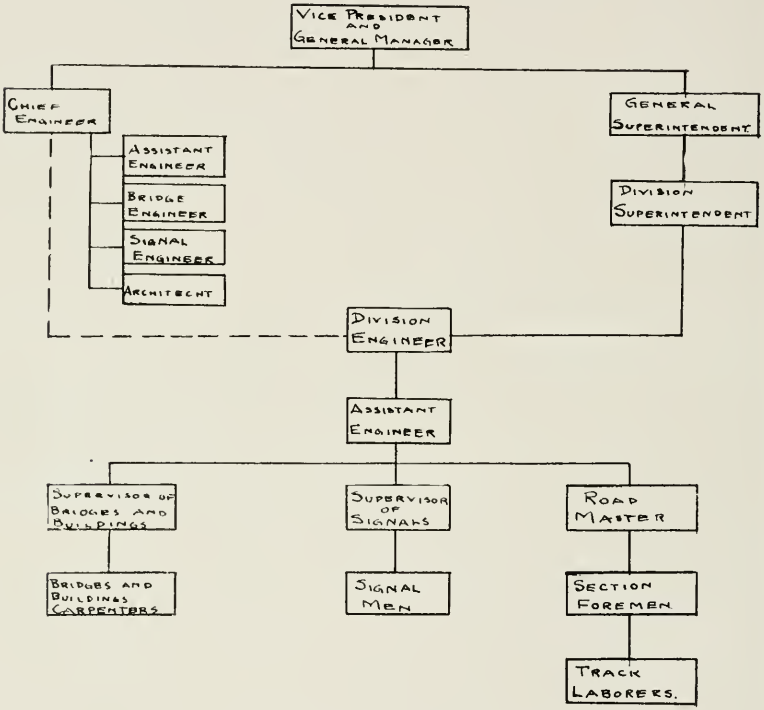
As stated, the Maintenance of Way forces are part of the larger operating department, along with the Mechanical and Transportation departments. In a purely departmental system, the division heads of these various departments report directly to the chief officers; while in a divisional organization, the division superintendent is made practically the operating head of his division, the other two departments reporting to him.

On the majority of the American railways the Chief Engineer is at the head of the engineering forces, and in some cases this officer is one of the vice presidents. Where considerable construction work is being done, there is often a separate department devoted to construction exclusively, while the Chief Engineer handles purely maintenance matters. However, the common practice is to combine the construction and maintenance work in one department. The Chief Engineer's office prepares the standards for the road, and gets up plans and estimates for the repair of existing structures and construction of new ones. The Chief Engineer has general oversight over all maintenance work, advising the Division Engineers on matters pertaining to their division. Assisting him are various staff officers, each in charge of certain features of the work.

The work of each division is in charge of a Division Engineer. This officer receives instructions of a general nature from the Chief Engineer, but reports directly to the Division Superintendent on all matters directly affecting the Division. The amount of mileage over which he has charge varies on different roads, depending upon the density of traffic and number of main tracks and sidings. The main line divisions usually average 200 miles, those on the Illinois Central being from 225 to 400 miles in length. It is customary to give each large terminal a separate divisional organization.

The Division Engineer has charge of all maintenance and

construction work on his division, except large construction work which is being handled by the Chief Engineer. He is directly responsible for the organization of the maintenance of way forces on his division, and upon him devolves the duty of planning the year's work. In this respect his duties are as much executive as engineering in character. He also acts as the company's representative in all questions of an engineering nature which arise between foreign roads, or with cities and states along the line. Very often the design of smaller structures is left to him. Whenever there is a wreck or a washout or a fire on the



company's property, or a heavy snow or rain storm, the Division Engineer is expected to be on hand and have traffic resumed within the shortest possible time. It has been well said, that, part of the early training of the Divisional Engineer should be to go without sleep for long periods.

The Division Engineer usually has an assistant who is responsible for the actual carrying out of the engineering work. The Division Engineer does the planning, and the assistant carries out these plans. In addition, there is the routine work of the division; preparing estimates of side tracks, getting up leases,

keeping the records and station plats up to date, giving lines and levels for foremen, etc.; which is done by the Assistant Engineer with the help of the necessary draughtsmen, instrumentmen, etc.

Reporting to the Division Engineer are the Supervisor of Bridges and Buildings, Supervisor of Signals, and Supervisor of Tracks or Roadmaster. On some lines, these officers, instead of reporting to the Division Engineer, report directly to the Division Superintendent.

The Supervisor of Bridges and Buildings, sometimes called the General Foreman of Bridges and Buildings, has direct charge of the maintenance of bridges, trestles, tunnels, docks, buildings, fuel stations, etc. In addition to these maintenance duties, he must make a personal inspection each year, generally in company with the Division Engineer, of the various structures under his charge; reporting all in need of renewal. Reporting to him are the various bridge and building foremen, bridge inspectors, foremen of painters, etc.

The Supervisor of Signals has charge of the various block and other signals, keeping them in repair. On certain of the eastern roads, this office is a very important one, and it is rapidly becoming so on the western roads, notably the Illinois Central.

The Supervisor of Tracks, or as he is sometimes called, the Roadmaster, is responsible for the maintenance of the track, roadbed, fences, right-of-way and station grounds. He also must make periodical inspections of the track under his charge, noting any defects. Assisting him in this work are the section foremen, each in charge of a section gang and one or more track walkers. Inasmuch as the maintenance of tracks is the largest part of maintenance of way work, the office of Roadmaster is a very important one, and the organization under him is larger than under either of the other two officers.

It will be well to take up more in detail the various aspects of the track work. The object to be attained is to permit the safe and comfortable passage of trains, to improve the appearance of the property and to reduce the cost of future maintenance. To permit the safe and comfortable passage of trains is the primary object. To accomplish this purpose, the track must be adequately maintained and closely inspected.

There is a very close relation between track costs and other operating costs of a railway. Poorly maintained track results in rough riding with constant wear and tear on the mechanical equipment. Bad track also materially reduces the tonnage which a given locomotive can haul, and increases the discomfort and actual danger to passengers. The operating officials of the country are coming to appreciate these facts more and more, and,

as a consequence, are dealing with maintenance of way questions in a broader and more serious manner. The constantly increasing weight of locomotives and cars has made the problem of track design and maintenance a most difficult and intricate one.

A great many persons have conceived a false notion of the relative magnitude of operation, maintenance, and construction work, not only in the railway field, but in others as well. In reality the amount of construction work is small in comparison with the others. As an example, consider the ties bought by the railways of the country, representing an annual outlay of $75,000,000.00. From 85 to 90 per cent of all the ties are used for maintenance; the remainder for construction. This is an index of the amount of maintenance and construction work on the railways. One should expect to find approximately the same ratio existing in other fields. The country has passed thru the great railway building period, and now it is largely a work of operation and maintenance. When construction work is undertaken, it is often really reconstruction, with the complexity of construction while maintaining traffic uninterrupted, an essentially more difficult problem than pure construction.

To secure the best results at a minimum cost in maintenance work, intensive organization and efficient system are essential. As stated before, the work to be done is varied in character and is spread out over a large area. At the same time the class of labor obtainable is often very mediocre, being largely made up of immigrants who cannot speak or understand English. Emergencies such as wrecks are constantly arising, which must be met without a moment's delay, for when the main line is blocked, minutes are valuable.

Several types of organization of the section forces have arisen on different railways. The method prevailing on most American roads is to subdivide the division into districts of varying length, depending upon the density of traffic and number of tracks, with a Supervisor of Track for each district. The average length of a district on the Illinois Central is 100 miles. Each district is further divided into sections of varying length, each in charge of a section foreman and section gang. In arriving at the proper length of a section, the average amount of track which can be maintained by one man is determined, and the length fixed on a basis of equivalent mileage. Of course it is necessary to determine the amount of siding and yard tracks equivalent to a mile of main track. One man per mile of single track and one a half men per mile of double track with a foreman and trackwalker to each section will ordinarily be force enough to maintain track in proper condition with good material.

This would allow six and ten men respectively in addition to section foreman and trackwalker on a six and ten mile section. The section forces on a great many roads are organized on these figures. One great defect of the present system, however, is that the size of the gang fluctuates with the season. In the Winter the gang is cut to about its normal size, and in the Summer increased to its full strength. This is done because of the fact that in winter it is impossible to perform certain features of track work, such as renewing ties, surfacing track, and clearing ditches, due to the ground being frozen. Just as soon as the weather opens up and the frost leaves the ground, the heavy maintenance work commences. This is the best time to renew ties and surface track. Ditches must also be opened up. In the Summer the grass and weeds must be cut from the right-of-way, and in the Fall the track must be prepared for Winter. The gang should be working at its greatest efficiency when this heavy work starts, but under the present system this is impossible. Instead, the new men are being broken in, and as a consequence the force is unorganized. In the Fall, when the efficiency of the gang is at its greatest, the majority of the men are laid off.

To lessen this evil, some of the railways are lengthening the sections and increasing the size of the gangs. In this way a skeleton organization is kept thruout the year, about which a new gang can be built in the Spring. In addition, the cost of overhead is cut considerably. When the introduction of motor cars in maintenance of way work, this plan should prove very satisfactory on many roads. The Union Pacific has obtained very satisfactory results from this method.

Another plan tried on a few roads, is that of having the heavier work, like ballasting and rail renewals, done by contract. This plan has been tried on the Michigan Central with considerable success. Of course there are a great many disadvantages to this method, but in certain cases, with proper inspection, there is no reason why it should not prove satisfactory.

On the majority of the railways any work of unusual magnitude is done by extra or floating gangs. These gangs vary in size from 15 to 40 men and are transported from place to place as needed. As the men are paid for the time they are being transported, the efficiency of the gang is necessarily low. The remedy is to have as much work as possible done by the regular gangs, increasing their size if necessary.

These are in general some of the leading features in the organization of the Maintenance of Way Department of the American railway. It is an exceedingly complex structure, and to operate it at the greatest efficiency requires the services of

individuals skilled in handling men. The Maintenance of Way Department is especially in need of this type of leader, men of resourcefulness and initiative, combined with a broad education along engineering lines. There are exceptional opportunities for the men possessing these characteristics. Such men can be found in the greatest number in our technical schools. The experience to be gained in maintenance of way work will be found to develop in one the qualities which will prepare him for larger and more diversified responsibilities.

RECENT TENDENCIES IN LOCOMOTIVE DESIGN

BY J. H. WESTBAY, '17

The careful designing of locomotives to meet definite requirements of service is a factor which is being practised more extensively on American railways from year to year. The natural outcome of this is more efficient locomotives, and at the same time a relative reduction in cost of train operation.

A step in the direction of more efficient freight train operation was made in 1903, when the Baltimore & Ohio Railroad had a Mallet articulated type locomotive built. The Mallet principle of using a single boiler resting upon two sets of drive wheels, each with a pair of cylinders, and having a jointed frame, appeared to be a means of operating trains with a large reduction in cost. By actual experiment with the Mallet locomotive, the Baltimore & Ohio proved such to be the case, as a result of a very large increase in train loads which could behauled with a single locomotive. Almost immediately locomotive builders began to receive orders for Mallet articulated locomotives, but after the first stages of enthusiasm were over, few of this type were ordered. The heavy expense for operation and maintenance of such locomotives proved, after a few years, that greater economy could be effected by the use of heavy, rigid, single-unit locomotives.

Under ordinary conditions of service, the Mikado, or 2-8-2 type locomotive, has become the standard type for hauling heavy freight. This type is well adapted to such service, because it combines high sustained steaming capacity with large cylinders, and a wheel base which furnishes ample adhesion, and at the same time is short enough to be used on short curves.

Under circumstances which render the Mikado type unsuitable for service, the Santa Fe, or 2-10-2 type is rapidly gaining favor. Such conditions are those found on roads over which freight service is very heavy, and on account of grades a ten-coupled engine is necessary to haul the heaviest freight trains. Although

a comparatively new type, the Santa Fe is fast becoming popular, and at present about a dozen of the leading railroads of the United States are using this type locomotive for their most difficult freight service.

Passenger service, like freight, requires locomotives having high sustained steaming capacity together with large cylinders, and in addition, drive wheels which are large enough to permit the locomotive to run at high speeds. These features are admirably combined in the Pacific, or 4-6-2 type locomotive. With a large firebox which is carried by a trailing truck, ample steaming capacity for severe service, large cylinders, and drivers which are in some instances 80 inches in diameter, the Pacific type is capable of hauling the heaviest passenger trains over any lines except those having very heavy grades. In these exceptional cases the Mountain, or 4-8-2 type is being successfully used, and is proving itself fully capable of meeting the severest conditions of heavy passenger service. The first Mountain type locomotive was built in 1912 for the Chesapeake & Ohio Railroad, and since that time engines of the 4-8-2 type have been built for the Rock Island, Missouri Pacific, Great Northern, Canadian Pacific, and Seaboard Air Line railroads. The New York Central Lines have very recently ordered thirty such locomotives.

Heretofore switch engines, as a rule, have received less attention in design than have the other types, this being due to the seeming unimportant service which is required of them. The natural result of this sort of designing has been cumbersome, inefficient locomotives for switching and yard service. In recent years, however, conditions under which such engines must operate have been studied more carefully, and locomotives are being designed to meet the definite requirements of present-day switching service. Such service calls for locomotives having a short rigid wheel base, large cylinders, and a very large per cent of the total weight on the drivers. The usual type of switching locomotive is the six-coupled, or 0-6-0, but a good many eight-coupled, or 0-8-0 locomotives are in service, and on two roads the coal consumtpion is so great as to be beyond the power of one man to fire efficiently. Such types as the Mountain, or 4-8-2, the ten-coupled, or 0-10-0 type is being used. In large freight yards, as those in East St. Louis, and Chicago, where long transfers are necessary, switch engines having a leading truck are found desirable, owing to the fact that the leading truck permits the locomotive to run safely at comparatively high speeds, improves its riding qualities, and makes it easier on the track. With these facts in view, the St. Louis Southwestern Railway has placed a number of heavy Mogul, or 2-6-0 type locomotives

in switching and transfer service in East St. Louis, and the Chicago & Western Indiana Railway has some of the same type in similar service in Chicago.

Other methods which have been adopted for securing greater economy and efficiency in locomotive operation are the use of the superheater, automatic stoker, firebrick arch, and the employment of relatively light engine parts. The superheater has been in common use on American locomotives for several years, and it is only in exceptional cases that a locomotive is built nowadays that is not equipped with a superheater of some type. The automatic stoker is not applicable to oil-burning locomotives, and it is desirable on coal-burning locomotives only in cases where and the Santa Fe, or 2-10-2, and all Mallet locomotives require a mechanical stoker to operate effectively. The brick arch has come into extensive use only within the last few years, but it is proving to be the means of effecting an increase in the efficiency of the locomotive. By causing a complex mixture of any cold air in the firebox with the hot gases before they strike the flues, the brick arch eliminates to a great extent any trouble from leaky flues, which is so common in locomotives which are not equipped with such an arch. The modern locomotive, on account of its power and weight, requires very strong parts, particularly the frames, axles, crank pins, driving rods, springs, pistons and piston rods. Materials which are very strong, yet comparatively light, are being extensively used in the heavy locomotive of today. In order to further decrease weight, without loss of strength, some roads are building their heavy locomotives with hollow axles, crank pins, and pistons, but are using material of superior quality for these parts.

Earlier American locomotives were built merely for the purpose of hauling freight and passengers, and the efficiency of the machine was seldom taken into consideration. The locomotive of today, however, must fulfill the requirements of heavy service conditions, and at the same time must operate with a maximum of efficiency.

LOCOMOTIVE ELECTRIC HEADLIGHTS

BY CRAWFORD P. McGINNIS

Special Representative, Pyle National Electric Headlight Co., Chicago, Ill.

Should you request a manufacturer of electrical machinery to build a lighting outfit of from 150 to 2500 watts capacity he would likely consider the job as of small consequence. Very likely, too, if the manufacturer was thoroughly familiar with steam railroad conditions and you specified that the apparatus was to be used as a headlight installation on a locomotive, he would consider the matter in a much different light. In fact, after properly considering the seriousness of even a temporary failure of the device, we should expect him, as a shrewd manufacturer—bearing well in mind the conditions which obtain on even the best of regulated railroads—to refer you to a concern experienced in this particular development of electrical machinery.

The writer appreciates that THE TECHNOGRAPH reader, who has had occasion to consider the problem of locomotive headlighting, is familiar with the angles which place it in a class alone. Therefore, it is for those who have given the subject no special consideration that this is written and the apparatus described is the product of the company whose interests the writer has the honor to represent.

Efficiency, as we have come to consider the term, is a recognized virtue, but in considering the design of an electric headlight equipment the efficiency factor, with respect to input to output relations, takes a place second to reliability. The farmer who, on the highway, depends upon the warning beam of the electric headlight to protect him on the crossings, may, in its absence, drive across the track with fatal result when a locomotive "runs dark". It makes little difference whether it was a man or a headlight failure in the consequences.

To the end of fool-proofing the apparatus positive tension brush-springs and fixed position brush holders are features of the bi-polar, compound wound generator the armature of which is directly connected by a short shaft to the rotor of a steam turbine. The turbine is of the impulse type with three stage steam expansion. The vanes are recessed and welded into the periphery of the rotor, which is of steel and to which is secured the centrifugal parts of the governor. Governing action is obtained by a balanced piston type of steam admission valve actuated by the centrifugal governor parts on the rotor. Governor adjustment is confined to responsible mechanics by retiring the

adjusting parts to the interior of the turbine casing. The shaft is carried on bearings which might, by the casual critic, be considered more than ample for the duty. Unlike the central station unit the locomotive headlight unit rests on very unstable foundations when the variable motions of a locomotive are considered and with the result that gyroscopic reactions must occur. Since the speeds of the various types of units range from 2800 to 3600 r. p. m. the bearings must be ample to absorb safely these re-actions. Hydrostatically, the turbine bearing oil chamber is drained of the condensation which collects from the exhaust steam and each renewal of the oil supply displaces a cubical equivalent of water. The turbo-generator unit is usually placed crosswise on the locomotive boiler where it is suitably piped for steam supply and exhaust.

The arc lamp, the source of the "head" light, is of the low (30) voltage type for the reason that a short arc gap is the most desirable for use in a reflector, a point easily appreciated when it is considered that the crater of the positive electode must be always coincident with or near the focus of the parabolic curve of the reflector. For the same reason direct current is used, making it necessary to feed only the positive electrode which is of soft carbon. The negative electrode is of good copper and deeply corrugated lengthwise to permit the maximum radiating surface and to provide clearance spaces for the oxidation, since the negative electrode is subject to high temperatures. Unlike the industrial arc lamp the locomotive type is so developed as to perform its functions regardless of the severe vibrations of the locomotive. The degree of perfection at present obtained is the result of years of experience.

The efficiency of the turbine is a nice problem in itself. Not wasteful, yet not so efficient that the leakage from a misused governor steam valve might run the unburdened unit to destructive speed—as when the engineman switches off the load of the arc lamp. But as a safeguard to safety measures each type of unit is provided with either a centrifugally operated friction brake or a displacing arrangement which shifts the rotor and vanes from under the nozzles when margins of safety are exceeded. The shunt winding on the field stabilizes the voltage for the cab, classification, indicator and other incandescent lamps when the arc lamp is off the circuit.

Aside from the trimming of the lamp and periodically filling the bearing oil cellars of the turbo-generator unit the equipment often gets no attention for months at a time. The better organized roads provide systematic inspection which, if universal, would make unnecessary many of the extremes of design, but

the builder must bear in mind that the worst conditions must govern.

The highly efficient gas-filled, tungsten, incandescent lamp is being utilized to some extent for projection in locomotive headlighting. With a filament of the concentrated or stereopticon pattern it is possible to bring into the focus of the reflector a more or less satisfactory amount of the light produced in the lamp. Theoretically, the highly concentrated filament of the extremely low voltage lamp is most adaptable to this service but in practice the distortion and irregularities of the locomotive type of reflector makes the 30-volt lamp equally effective, the foci of the several curves of a poor reflector more nearly coinciding with the field of the larger filament. To insure the close focal adjustment necessary when the light source is relatively low, as is the case with the incandescent lamp compared with the arc, a "micrometer" device is provided for longitudinal, lateral and vertical movement of the lamp in the reflector.

That the unforeseen is a specter always in the vision of those who operate our railways is evident in their precautionary measures. Fixed signals—positions by day and colors by night—indicate the expected dangers and the engineman is on his guard. It is the unwitting or the careless act of man and the hand of God which makes necessary the effective air brake on our fast trains of today. But the most highly developed brake is more or less dependent, for its effectiveness, on the engineman's vision.

To give that keen perception and vision as nearly as possible the same chance by night as nature provides by day, and to warn teh wayfarer and the trespasser, the Pyle National Electric Headlight pioneers attacked the problem some eighteen years ago with the result that some 35,000 equipments are in successful operation on the railways of the world.

COMPOUNDING AND SUPERHEATING IN LOCOMOTIVE PRACTICE

BY E. G. YOUNG

To the person familiar with the engineering of power-plants and especially the phases relating to the steam-engine, the locomotive—a true power-plant in itself—offers some questions which may be rather puzzling. One of these is the non-use of compounding, in consideration of the fact that this practice is regarded as so essential in stationary reciprocating engines of high power. The compound principle has been used and to some extent still is used in locomotive construction, and the story of the growth and decline of the practice forms an interesting and much misunderstood chapter in the history of locomotive development in America.

Compound locomotives were in successful operation on the railways of France and England for several years before their introduction into this country, and the history of compounding in America begins with the importation in 1887 of a "Webb" type compound from England. This engine had three cylinders: two outside using the steam direct from the boiler, and a large one between the frames utilizing the exhaust from the two high-pressure cylinders. In 1889 the first American compound was built by the Baldwin Locomotive Works, of a type later known as the "Vauclain" system, having four cylinders; these were arranged in pairs, a high-pressure and a low-pressure on either side. The following year the "cross-compound" or two-cylinder compound was introduced, the principle being borrowed from stationary practice, though previously applied in Europe.

A general review of the various mechanical adaptations of the compound principle as used both in America and abroad serves as the best summary of the history of compounding practice. For convenience, a classification may be based on the number of cylinders used, whether two, three or four.

Two-Cylinder Compounds

This type has a high-pressure cylinder on one side, and a low-pressure cylinder opposite, the ratio of their diameters being usually about 1:1.5. In starting, steam is admitted to the low-pressure cylinder through a "bleeder" valve, the pressure being reduced to such an amount that the total pressures on the respective sides are equal. This type was introduced in Europe in the seventies, and in the United States in 1890. It was ex-

tensively used in freight service and to some extent in passenger locomotives, but has disappeared from use entirely.

Three-Cylinder Compounds

1. The French type, with one high- and two low-pressure cylinders of approximately equal size, the former being located between the frames and the latter outside. This type was never introduced into America and has been entirely superseded in France.

2. The Triplex type—the latest American development in compounding practice. Four of these locomotives have been recently built, each having six cylinders. There are two high-pressure and four low-pressure cylinders, each of the former exhausting into two of the latter and all being of equal diameter—it is thus merely an extension of the old French principle, combined with the Mallet system of articulation, which will be referred to later.

3. The Webb type, with two high-pressure and one low-pressure cylinders, the latter between the frames. The history of this type began and ended in America with the importation of the "Pennsylvania" in 1887, but the Webb system was in extensive use in England and many examples remain in service.

Four-Cylinder Compounds

1. The Vauclain type. This type has a pair of cylinders on each side of the engine: one high- and one low-pressure. They are placed one above the other, and the two piston rods are connected to the same crosshead. This type was introduced by the Baldwin Works in 1889 and was applied extensively to both freight and passenger engines for about fifteen years. A few examples of this system of compounding are still to be found in service, but none have been recently built.

2. The Tandem type. The first engines to use the tandem compounding system were built about 1898, and this form was adopted in a limited degree by most of the American builders. It is a variant of a type previously employed to some extent in Europe. There are a pair of cylinders on each side located end to end, a piston in each cylinder being mounted upon a single piston-rod traversing the two. The tandem type was not extensively popular in this country, and none have been built in over a decade. A few are still to be found in service, however.

3. The Balanced type. There are four varieties of balanced-compound locomotives, the essential principle of all being the same. This is the use of two cylinders between the frames and two outside; the pistons of the two right cylinders are at opposite ends of their respective strokes and the same of the cylinders on the left. Adjacent reciprocating parts being 180 de-

grees apart in phase, a high degree of mechanical balance is secured. In the "balanced" class, a subdivision may be made between those types which have all of their cylinders driving the same axle, and those with a divided drive. In the former class are the Worsdell and von Borries types; in the latter the Cole and de Glehn types. The last-named type was developed in France, and is in almost universal use in passenger service in that country today, and has also made its way into other parts of Europe. A single engine was brought to America in 1903 for experimental purposes. The de Glehn has its pair of low-pressure cylinders between the frames under the smoke box, the rods being connected with the front couple axle. The high-pressure cylinders are outside and located far enough back under the running board so that they may be connected to the second coupled axle without the use of excessively long rods. The Cole type is an American variant of the de Glehn; the low-pressure cylinders are outside of the frames in their normal location for American practice; they drive the second axle. The high-pressure pair are located farther forward between the frames, and drive the front coupled axle. This type cannot be said to have gone beyond the experimental stage as only five engines were built (1903-4). In the second class of balanced compounds, the Worsdell compound has its low-pressure cylinders between the frames and the high-pressure pair outside, while the von Borries type is exactly opposite. The Worsdell type has never been used in America, but has found considerable favor in England. The von Borries type has been very extensively used in America as well as abroad, having been introduced into this country by the Baldwin Works in 1902, and being generally known as the "Baldwin" balanced compound.

4. The Mallet type. In this type the high-pressure cylinders drive one set of wheels and the low-pressure pair an independent set: a Mallet locomotive consists therefore of two complete pairs of engines under a single boiler. On account of the large number of driving wheels that may be used, and the resulting greater adhesion and tractive effort, very large hauling capacity is developed. The high-pressure engine is located under the fire-box end of the boiler and is rigidly fastened to it; the low-pressure engine is ahead, its frame connected by a hinge to that of the high-pressure engine. The front of the boiler slides laterally upon bearers mounted on the frames of the front engine; by this means an excessive rigid wheel-base is avoided and the engine is rendered suitable for service on track having rather sharp curves. The Mallet type receives its name from its inventor, and the principle was used abroad for many years

prior to the construction of the first locomotive of the type in America, though the majority of those built abroad were for very light service. The first American Mallet was built in 1903 by the American Locomotive Co.

As has been said, the first compound types began to come into use in the early nineties. At Chicago in 1893 the practice of compounding received a great impetus, as all of the types of compound locomotives then in use, both American and foreign, were represented in the locomotive exhibit. An interesting feature of the extension of the principle in the following years was the construction of experimental engines; several American builders did this, loaning the engines to roads interested, and furnishing with them crews expert in the running and repair of the type represented. The interest in compounding in 1904 is well shown by the fact that of the eight engines tested by the Pennsylvania Railroad at their testing-plant at the St. Louis Exposition, six were compounds: four balanced, one two-cylinder, and one tandem. The number of compounds continued to increase for several years, the balanced type gaining much favor for passenger service, and the Vauclain and two-cylinder types in freight service; the Baldwin Works sponsored the two former types, and the American Locomotive Co., the latter. Within two or three years after the "Fair", the use of the Mallet type began to spread in spectacular fashion, and the size and power of the engines increased almost as rapidly as the number in use. The final stage of ten drivers on each side, with leading and trailing trucks, was reached in 1910.

Beginning with 1907 there was a tremendous falling off in the number of compounds built, for the "balance of power" (which really had not been a balance at all, since the partisans of compounding held the advantage) was completely upset by the advent of the superheater. In order to understand the issue between the compound principle and the use of superheated steam it is necessary to know something of the gain in efficiency produced by each improvement. In each case, the gain effected is dependent on the fact that in any steam engine there is a wide variation of the temperature of the cylinder-walls during the course of each revolution; steam at its highest temperature is admitted to the cylinders when the walls are the coolest, having just been exposed to the atmosphere by the opening of the exhaust ports. When saturated steam is used in simple cylinders, the contact of the steam with the metal produces a condensation of from 20 to 50 per cent. of the total steam admitted to the cylinder. Both of the improvements under consideration are means of reducing this condensation loss. Compounding divides

the range of pressure in each cylinder and thus the variation in temperature; the exhaust of the high-pressure cylinder does not open to the atmosphere, but in the low-pressure cylinder, and due to decrease in the temperature range, the condesation is greatly decreased. The loss due to condensation is overcome by compounding quite satisfactorily at low speeds, but in the neighborhood of two hundred revolutions per minute and above, the compound engine is no more economical than the simple, and often less so. It has also been proved by many tests that compound locomotives are most economical under conditions of sustained heavy loads, frequent stopping, starting, or running with closed throttle greatly decreasing the thermal economy. Under the most favorable conditions, those of steady pulls on long grades at relatively low speed, the compound will show an economy at least 25% better than the simple engine.

The superheater attacks the problem of condensation in another way: by attempting to prevent it entirely. If the steam is provided with sufficient excess heat ("super"-heat) so that a sufficient quantity may be given up to warm the cylinder walls without reducing the steam to the saturation temperature, there can be no condensation. With the present practice of admitting steam to the cylinders at temperatures ranging from 500 to 600 degrees Fahrenheit there is a little superheat generally remaining in the exhaust steam, showing that the condensation has been done away with in a large degree if not entirely. The superheater becomes efficient at a speed of eight to ten miles per hour, and increases in efficiency as the speed increases indefinitely. As a conservative estimate, the economy of the superheater engine may be placed at 35 per cent better than that of the simple engine using saturated steam, and from 5 to 40 per cent better than the compound, the higher saving taking place at the higher speeds.

The comparison between the mechanical features of superheating and compounding is of interest. The former is simply a rearrangement of the boiler tubes in such a way that the steam after leaving the dome is divided into a number of small streams, each of these being led through a channel in which it is exposed to the further action of the hot gases. There are no moving parts. Compounding, on the other hand, from its very nature introduced a considerable degree of mechanical complication; in some types the moving parts become of excessive weight; in others the difficulty of making certain frequently required repairs is very greatly due to the inaccessibility of the parts; in all types the "starting-valves" are frequent sources of trouble. These are devices to admit live steam to the low-pressure cylin-

ders for the first few revolutions, in order to provide sufficient tractive force to start the train. It is evident from what has been said of the thermal principles that there is little additional gain when compounding and superheating are used on the same engine, since the former merely palliates a loss which the latter removes entirely.

Two types of compounds, however, survive—the balanced type, and the Mallet. It is noteworthy that in each of these it is rather the mechanical principle than the compound feature that is of importance: in one, perfect mechanical balance, and the resulting suitability for high-speed operation; in the other, the large hauling capacity that is made possible by the use of the articulated principle. This has recently been extended (in the "Triplex" type) by the use of three pairs of cylinders and three sets of driving wheels, the third pair being located under the tender; one of these engines has accomplished the remarkable feat of hauling a train nearly three miles long over a division.

In this connection, something further should be said of the balanced compound. The Baldwin (or von Borries) type, having the high-pressure cylinders between the frames and all four cylinders located on the transverse center line of the saddle is the type that still holds a limited place in American practice. Mechanically there are three varieties of this type:

All cylinders driving the front coupled-axle through a very short set of main-rods.

All cylinders driving the second axle, the inside main rods being "bifurcated" to clear the front axle.

All cylinders driving the second axle, the inside pair being higher in the saddle castings, and inclined so that the rods clear the front axle.

The latter is much the best type and has been employed by the road using the largest number of these engines on all of their later construction.

In order to obtain the gain which superheating produces over and above that due to compounding, late compounds, both Mallet and balanced, have been equipped with superheaters. There have been three methods used in combining the superheater with the compound principle:

The steam is superheated before passing into the high-pressure cylinder.

The steam passes directly from the boiler into the high-pressure cylinder, and is superheated between the high-pressure exhaust and the low-pressure admission.

The steam is superheated at both of the points named.

These arrangements are called respectively initial, intermediate, and two-stage superheating. In engines of the Mallet type the intermediate and two-stage plans have been frequently employed, but tests have shown conclusively that the largest gain came from initial superheating. In the case of passenger engines so equipped the economy is a little better at low speeds and as good at high speeds as the simple engine using superheated steam. In this way the inefficient operation of the compound saturated locomotive at high speeds is avoided, while the mechanical balance is retained. It remains to be seen, however, whether this is to be the solution of the heavy passenger engine problem or whether the plan now in common use in Great Britain is a further improvement—that of using four simple cylinders.

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THE TECHNOGRAPH, Champaign, Ill.

EDITORIAL

The editor has been asked, "Why is THE TECHNOGRAPH not a larger magazine?" It certainly is not because of the lack of material, as students, professor, and others as well, have always responded with wonderful willingness. A great percentage of the blame can be placed on the attitude of the students. In the first place, every engineering student ought to subscribe for the magazine, which surely is not the case now. Then, if the students would trade with the advertisers in THE TECHNOGRAPH, telling them where their ads were noticed, the advertising end would be greatly assisted. Another big help would be to ask those whom you patronize, why they do not advertise in THE TECHNOGRAPH.

Advertising, circulation, and size of a magazine go hand in hand; no one of them can get very far ahead of the others. If the size is to be boosted, then the advertising and the circulation must also be boosted.

Since THE TECHNOGRAPH is the magazine of the engineering school, its size and quality reflects the school itself to those outside. Hence every engineering student should be vitally interested in it. Are you doing your share?

THE TECHNOGRAPH is not run for any great source of revenue for the staff, and any increase in the advertising and circulation, will be put into the size and quality of the magazine. Help us boost.

THE NUCLEUS OF AN ENGINEER'S LIBRARY

An Editorial from the Engineering Record.

It is surprising to find how common is the practice among students in engineering schools of selling their textbooks as soon as they pass the courses wherein the books are used. During the last year, in the classes in mechanics of materials and hydraulics at a well-known technical school of high standing, there were 89 and 114 students respectively. The two book stores at which textbooks are sold to these students report that 76 copies of the mechanics of materials and 97 copies of the hydraulics were disposed of by them during the year. This shows that 13 students in one and 17 in the other, or 14.6 and 15 per cent respectively, obtained their books from men who had previously taken the courses, or studied the book of a classmate, or possibly in extreme cases went without the books altogether.

If this condition obtains in such important fundamental sub-

jects, constituting the very foundation of most constructive engineering, what must be the state of affairs in the less important ones? There are two reasons, both poor, why students sell their books. In the first place, there are a good many men in stringent financial circumstances who dispose of one set in order to buy others. Even this is false economy and the practice should not be followed until all other resources have been drawn upon. The second and more common reason for dispensing with books lies in the mistaken idea that as soon as an examination in a subject is passed there is no further need for the books pertaining to that subject. This practice is by no means confined to needy students but is engaged in by those young men who do not appreciate the relation of one course to those that follow it. Neither do they realize that their books are part of their stock in trade, to be used as necessity demands. It is not only at graduation that books are sold. It is all through the college course, and when a copy of the book on mechanics of materials is disposed of at the end of the term, there is little or no thought in the mind of him who sells it that he may have many occasions to use that book in his machine design or bridge design courses that follow.

Experience teaches that one's textbooks are the best reference books, not only in college but in after years while engaged in engineering practice. By studying a book daily for a term one becomes familiar with it; he knows where to find things in it and he understands its limitations. In busy times, when it becomes necessary to make use of a reference book, the old textbook with its marginal notes and its familiar diagrams, formulas, and most important of all, with its familiar notation, is a great source of help—a friend in need. Not uncommon is it that in making reference to some book in which methods and notations are new one becomes entangled in the search for the meaning of this or that particular letter in the very formula that is needed, but because the meaning is not clear or the significance of the letter is not stated he abandons the book without getting the desired information. The book may be just as good or better than others of its kind, yet its value is greatly lessened because of its unfamiliar pages. The next best thing to having information in mind is to have it in a book, to know where to find it when wanted and how to use it when found. It is just this that makes engineers' handbooks so desirable, and even these books are only half appreciated until one becomes familiar with them. But no handbook takes the place of a good college training coupled with a workable library of technical books upon which many hours have been spent in study.

Students should keep their textbooks, whether they think they will be of further use or not. Since most students who go through engineering courses follow engineering, it is a fair presumption that the books will be used later. In a well-managed course in engineering the books are not selected at haphazard but are carefully chosen. By preserving those used in classes and by adding a few other standard ones each year a fairly good nucleus will be formed by commencement day around which a technical library can easily be collected. And with a good supply of books at hand the young engineer will be more likely to continue his studies after graduation than if his only available supply rests in the city library, if indeed he is fortunate enough to be near one.

E. E. NOTES.

At a recent meeting of the Electrical Engineering Society I. W. Fisk gave a very welcome and interesting informal talk upon "The Principles and Operation of Various Types of Automobile Magnetos." By the use of several magnetos in operation he demonstrated and explained the action and theory of ignition devices and discussed the advantages and disadvantages of the different systems. In his terse, energetic style he made clear many interesting phenomena occurring in ignition practice.

At the last meeting of the Illinois Electrical Association, held at the University, papers were read by Professors Paine and Brooks of the Electrical Engineering Department upon "The Regulation of Feeder Voltage" and "Rate Making." Professor Paine's paper was illustrated by slides showing various types of voltage regulators and results attending their use. A paper by Professor Brooks upon "The Relation of Lightning to Architectural Interiors" was read before the Illuminating Engineering Society in New York, February 10. In this paper he urges effective correlation between the design of an interior and its illumination, and indicates methods of lighting interiors with this object in view. He also discusses non-uniform illumination, control of contrast, effective residence lighting, and advantages of directed lighting. This paper is of value particularly to architects and illuminating engineers, and an application of its principles to such glaringly dtfective lighting installations as those in University Hall Chapel, Morrow Hall and the Library would result in much more pleasing and satisfactory illumination. The present high efficiency of the incandescent lamp has relieved the engineer of the problem of obtaining sufficient light, and gives him an opportunity to develop the artistic and the scientific in illumination.

D. G. EVANS.

M. E. SOCIETY NOTES

Since the last number of The Technograph was issued the M. E. Society has held two meetings, both of a business nature. At the first meeting, February 10th, the officers for the semester were chosen. They are as follows: President, G. S. Schaller; Vice-president, R. S. Mason; Secretary, V. S. Day; Treasurer, G. T. Avery. The retiring officers gave reports on the condition of the affairs of the Society.

The matter of an Engineering Dance was discussed and a resolution favoring the dance was passed.

The second meeting was held March 9th. It was entirely of a business nature. Booklets, received from the Parent Society, explaining the relations which exist between the Student and Parent Societies, were distributed. The booklets contain information of value to any member of the Student Branch. Copies may be had from President Schaller.

The members were reminded that the time for lectures by students is at hand and that the cup contest will be the principal source for programs for the semester's meetings.

Mr. F. Evans was elected to serve as M. E. Society representative on the Engineering Dance Committee.

The movement for the securing of a pin for the Society is well under way. Every Mechanical Engineering student in the University should wear the pin. It is attractive but not bold, and may be had for a very reasonable price.

V. S. Day.

THE HIGHWAY SHORT COURSE

BY W. A. HIMMELREICHER

About a year ago, the Highway Short Course, held January 10 to 21, 1916, was announced and in the fall, 700 postal cards were sent to all interested. About 102 replies were received. An attendance varying from fifty to one hundred and seven was recorded. Among those resgistered were County and Township Superintendents of Highways, Contractors, Materials Men, Inspectors, Farmers, and representatives of various other groups interested in highways.

Arrangements for the Short Course were completed by a small committee consisting of Dr. I. O. Baker, chairman, and Messrs. M. B. Garver and C. C. Wiley. During the morning, the men were divided into two sections, A and B. From 8 to 10, Section A received instructions regarding bridge construction from Mr. Garver and Section B received instructions regarding road construction from Mr. Wiley. From 10 to 12, the sections changed

places, Section A being in Mr. Wiley's charge and Section B, in Mr. Garver's charge. Some afternoons were spent listening to lectures given by engineers and chemists, others were spent watching demonstrations in the various laboratories. Every evening, a semi-popular lecture was given. In addition to the lectures for instruction, there were exhibits consisting of several models of highways in all stages of construction and a series of pictures loaned by the Federal Government. In addition, the Barrett Manufacturing Co. had an exhibit of pictures showing the use and results of their paving materials. That men appreciated the efforts of their instructors was shown by the fact that they presented Mr. Garver with a reading lamp and Mr. Wiley with a portfolio.

At the close of the Short Course, the following resolutions were drawn up:

"We, the men interested in the building and maintenance of roads, who have been in attendance at the Short Course in Highway Engineering at the University of Illinois, January 10 to 21, 1916, before leaving desire to express our hearty appreciation of the efforts of the University authorities in providing this course, and of the individual instructors who have done so much to make it a success.

"Further, we urge that a similar course be provided in each succeeding year, as we believe that there is no one way in which the money of the citizens and taxpayers of the state can be more effectively spent than in diffusing the latest and best information on highway construction and maintenance to the men actively engaged in this work."

On January 7, the C. E. Club assembled to listen to a talk given by Mr. J. H. Miller, '16, on the U. S. Geological Survey.

The Geological Survey was organized in 1879 and has since grown to a department employing permanently from 800 to 900 engineers and geologists, besides a large number of temporary employees during the field period. The Geological Survey is divided into three departments, namely: topographic department, geological department, and hydrographic department. The topographic department, employing permanently about 200 topographical engineers, maps out all sections of the country. The geological department, employing permanently about 150 geologists, puts all mineral deposits, rock formations, and underground water courses on the map. The hydrographic department, employing eighty hydrographic engineers, gauges the flow of streams in all sections of the country. Office work, such as plotting and

preparing maps for engravers, and writing up notes and reports for publication, is done in winter.

The Geological Survey has printed about 2300 different maps covering about forty per cent of the United States and is mapping out somewhere near 20,000 square miles each year. Each map costs from $3,000 to $5,000 to make and is sold for ten cents. The department engraves and prints its own maps, but its bulletins are printed by the U. S. Bureau of Printing and Engraving.

At the meeting held January 25, the following men were elected to hold office for the second semester:

C. G. Jennings.....President
E. A. Lawrence.....Vice President
V. A. Pecchia.....Secretary
R. T. Elliot.....Treasurer

On March 3, Mr. H. R. Thomas gave a talk to C. E.'s on "Experiments on Railroad Tracks". The experiments, which are being performed on the I. C. tracks near the round-house, are being made by a joint committee of the American Society of Civil Engineers and the American Railroad Engineering Association under the supervision of Prof. Talbot. Mr. Thomas had with him several of the instruments used on the tests. He explained the use and principles of operation of these instruments, some of which had to be designed for this kind of work only. Inn addition, the speaker had a number of photographs of various stages of the tests.

The tests art being made to determine stresses in tracks under static and moving loads, behavior of tracks and roadbed under these loads, advantages and disadvantages of certain forms and depths of ballast, etc. The tests will be continued as soon as the weather permits. Visitors are invited to come out and to inspect the work.

W. A. Himmelreicher.

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The Technograph

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General View of Viaduct

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LATERAL PRESSURE OF WET CONCRETE ON COLUMN FORMS

By A. B. McDANIEL, *Assistant Professor of Civil Engineering, University of Illinois,* and N. B. GARVER, *Associate in Civil Egineering, University of Illinois*

Importance of Subject

It is necessary to have accurate information concerning the pressure exerted by wet concrete so that the forms may be economically and safely designed and constructed. The use of unnecessarily heavy forms incurs an excessive expense, especially with the high cost of lumber. Many failures of concrete structures have taken place and they are largely due to the lack of knowledge of the action of wet concrete on forms. Such failures usually occur in columns and posts and are due to the high pressures caused by the pouring of concrete. The failure of the forms entails temporary injury and incurs considerable delay and expense.

Previous Investigations

Several investigations have been carried on in the past to determine the lateral pressure exerted by wet concrete on forms, but very little accurate information has been derived from them.

In 1894 Mr. Ernest McCullough made a series of tests in which the presssures were measured by placing a 7/8-inch board in the side of a form and pouring in concrete until the board broke. The pressure obtained was equivalent to that of a liquid weighing about 80 lbs. per cubic foot. The weight of the equivalent liquid was probably only about one-half that of the concrete. Owing to the crude manner in which these experiments were conducted, little importance can be attached to the results.

In 1908 a very extensive series of tests, lasting throughout the season, was carried on by Major F. R. Shunk, during the construction of the Mississippi River Lock No. 1 near Minneapolis, Minnesota. The tests were made during the pouring of monalithic blocks of concrete 25.75 feet high. The concrete was very wet, and weighed about 152 pounds per cubic foot. The lateral pressure was measured by means of a piston connected to a scale

beam. The results indicated that a hydrostatic pressure corresponding to that of a liquid weighing 152 pounds per cubic foot was obtained at first; but as the head increased the concrete began to act more as a solid, so that later the pressure remained practically constant. It was also found that the head at which the concrete began to act as a solid varied with the rate of pouring, the temperature, the pressure, and the condition of agitation of the surface.

In 1913 Mr. E. B. Germain, assistant engineer for the Aberthaw Construction Company, carried on a series of tests during the construction of a mill building in Cambridge, Massachusetts. A wet 1:1½:3 mixture was poured at a rapid rate into two columns 20 inches square and 20 feet high. The gages were hot-water bottles filled with mercury, so that the lateral pressure was measured by reading the level of the mercury in the tubes. A hydrostatic pressure equivalent to that of a liquid weighing from 140 to 150 pounds per cubic foot was obtained.

UNIVERSITY OF ILLINOIS LABORATORY TESTS

Two series of investigations were made during the college years 1913-14 and 1914-15 by undergraduate students under the supervision of Professor McDaniel of the Civil Engineering department, University of Illinois. The tests were made upon two sizes of column forms and the pressures were measured at five points along the sides of the forms by diaphragm pressure gages. Following is a description of the apparatus, materials, and method of making the tests.

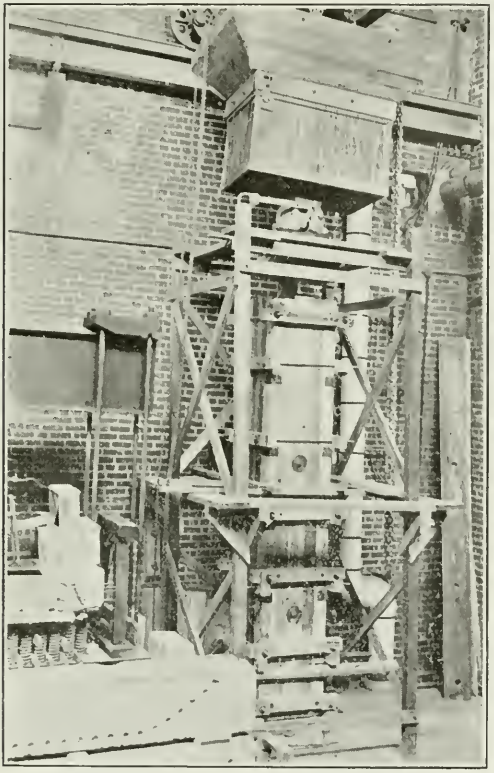
Apparatus

The tests were made on 12-inch and 20-inch square column forms, the height being 12 feet in both cases. The forms were made of planks with ship-lap joints, and were built of sections which were interchangeable, 4-inch sections being added to the 12-inch form to make the 20-inch form. The parts of the forms were held together by wooden yokes and steel rods. No trouble was experienced with leakage from the forms. Five threaded cast-iron rings were set into the forms at various places and were used to hold the pressure gages during the tests.

The pressure gages were made especially for these tests, and were of a type which was successfully used to measure the earth pressures during the construction of the Pennsylvania Tunnels in New York City. Each gage consisted of a flexible German-silver diaphragm acting upon a reservoir containing mercury. The pressure was indicated by the pressure of the mercury in the tube. The graduation of the tube was arbitrary, so that it

was necessary to calibrate it. A thick layer of grease covered the diaphragm during the tests, to protect it from temperature changes and small falling particles.

A unique method was used for determining the height of the concrete in the forms. Brass tubes were set into the forms at



General View of Column and Pouring Equipment

one-foot intervals. Wooden plugs fitted with wires and brass screws were set into these tubes. Copper strips wired to electric lamps were fastened over the holes so that the lamps were lighted when the plugs were forced out and made contact. The plugs were kept well filled so that they would slide easily in the tubes.

A wooden tower was used to support the hopper and brace the column form. A sheet-iron funnel, supported on the top of the tower, directed the concrete from the bottom dump bucket to the center of the form. The funnel was easily removed, so

that the form could be lifted at the end of each test in order to remove the concrete before it had set.

The bucket was of the bottom-dump type, and was constructed of sheet steel. The original capacity was 18 cubic feet, but was increased to 48 cubic feet by building a wooden extension on top. The bucket was elevated and transported by a 5-ton hand-power traveling crane.

Materials

The materials used in the concrete were Universal Portland cement, glacial bank sand, and broken stone.

The cement was found by tests to conform to the standard specifications of the American Society for Testing materials.

The sand came from a deposit of glacial drift near the Wabash River at Attica, Indiana. It was clean and well graded.

The stone was crushed limestone from Kankakee, Illinois. It had been previously passed through a one-inch screen and over a quarter-inch screen.

The ingredients for the concrete were proportioned by volume. A 1:2:4 mixture was used in all the tests. The concrete was mixed in a one-third cubic yard motor-driven batch mixer. For the 12-inch column tests, the concrete was mixed in two batches, the first being dumped onto the floor and later incorporated with the second batch. For the 20-inch column tests, three batches were necessary. The material was dumped from the mixer onto the concrete mixing floor and was there shoveled into the skip. The skip was then raised by a traveling crane and moved into position over the column form.

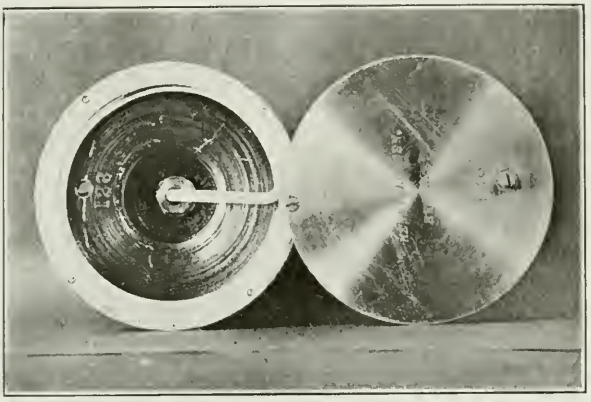
After the concrete was mixed preparatory to the pressure tests, sample cylinders were molded and tested to determine the crushing strength of the concrete. The average strength of twelve 8 x 16-inch cylinders was 1040 pounds per square inch at an age of 28 days.

Method of Making Tests

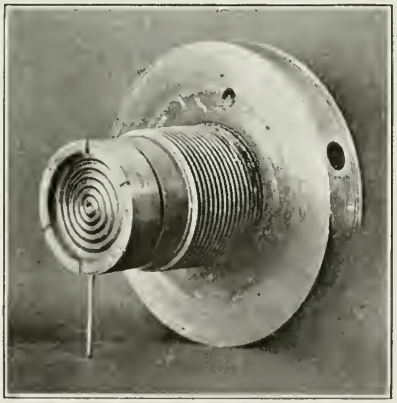
A bourdon gage was calibrated with a Crosby Gage Tester and then connected to the end of the gage calibrator to which the pressure gages were attached. The gage calibrator was connected to a 60-foot standpipe in the hydraulics laboratory of the University. By means of valves, the static water pressure was applied and lowered a pound at a time by lowering the level of the water in the standpipe. The gages were calibrated before each pressure test. The temperatures of the air and the water were taken during each calibration. All the gages were read simultaneously for each change in pressure, and the readings were recorded.

During the calibration of the gages, the concrete was mixed, shoveled into the skip and the latter raised to its pouring position over the column form. The calibrated gages were placed in their rings in the form and at a given signal the pouring began.

Nine men were employed on each test. One man had general supervision of the test, and gave gong signals for the reading



Front View of Pressure Gage



Rear View of Pressure Gage

of the gages. One man noted the time at which the electric lamps were lighted by the forcing out of the contact plugs. Five observers read the gages. One assistant manipulated the gate at the bottom of the skip, and another in the skip kept the flow uniform through the gate.

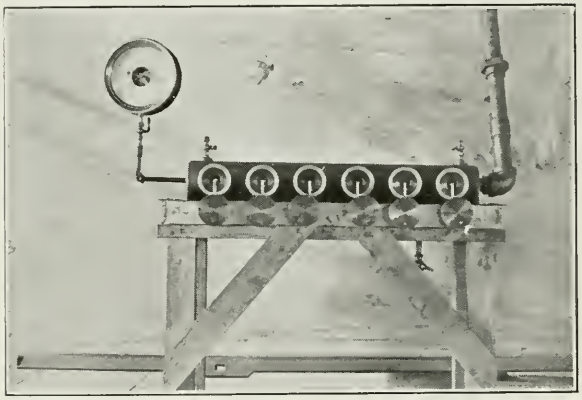
The gate of the bucket was opened wide enough to secure a continuous flow of concrete through the hopper into the form. A gong was struck every fifteen seconds, and the highest pres-

sure reading during the interval was recorded by the observer at each gage. Several tests were made on each size of column, and the consistency of the concrete and time of pouring were varied to determine the effects of these factors upon the lateral pressure.

Observed Results

Calibration curves were plotted for the readings of the Bourdon and of the pressures gages. These curves were then used to reduce the observed readings of the pressurage gages for each test.

The tests of the 12-inch column form varied in time of pour-



GAGE CALIBRATION APPARATUS

ing from three to nine minutes and of the 20-inch column form were six and fourteen minutes. The consistency of the concrete varied from quaking or medium to very wet. Difficulty was experienced in securing a uniform rate of pouring during any one test. It was noted that the material as it discharged from the skip was not of a uniform consistency; due to the loss of water in handling the concrete and the tendency of the wetter, upper section of the concrete in the skip to discharge before the general mass.

An effort was made to determine the effect of impact by special tests in which the concrete was poured in layers one foot in depth, and an intermission of fifteen seconds between successive layers. The highest reading on each gage during the pouring of each layer of concrete and also the lowest reading during the succeeding interval was recorded. The results gave in each case a definite reduction in pressure after the pouring ceased; but as

only one test was made on each size of column, there is insufficient information for the making of any conclusions.

Conclusions

The tests were not sufficiently comprehensive to permit of the statement of any definite laws regarding the lateral pressure of wet concrete. Conditions of testing were found to be so variable that it is difficult to make comparisons between the results of different tests even on the same size of column form. However, it is believed that the following general conclusions are justifiable.

(1). The lateral pressure increases with the head up to a certain point, after which the pressure remains nearly constant until the pouring ceases. It is probable that during the early part of the pouring, the concrete is supported by pressure upon the base of the form, and later a considerable part of the concrete is supported by arch-like action on the sides of the form. In this respect the action of green concrete seems to be similar to that of grain, seeds, clean dry sand, etc., in a bin.

(2). The lateral pressure in general corresponds to hydrostatic pressure for wet concrete.

(3). The lateral pressure increases with the rate of pouring and the degree of wetness of the consistency.

(4). The lateral pressure is about the same for column forms up to 20-inch square.

Field Tests

A series of field tests were conducted on a reinforced concrete arch viaduct which was under construction across the North Fork of the Vermilion River at Danville, Illinois, during the summer of 1915.

The object in making these tests was to get more data than had been obtained in the laboratory, and also to get information by which a comparison might be made of lateral pressures under laboratory and field conditions. It is often argued that results obtained in the laboratory are of little value because conditions do not approximate those existing in actual construction work.

The structure upon which the tests were made offered an excellent opportunity for making such tests because of the character of the construction and the method of pouring the concrete. Also the contractor and superintendent of the work were interested and offered every assistance possible.

The viaduct is of the arch-rib type, with spandrel posts, floor beams, and slab floor. The tests were made on the spandrel posts

of the longer spans. These posts have a cross-section of 23 x 30 inches, and a maximum height of about fifteen feet. They have both vertical and horizontal reinforcing bars.

The vertical reinforcement consists of one-inch square bars, of which one is placed in each corner of the post. The horizontal bars are one-half inch squares spaced about three feet on centers. Particular care was taken to so locate the pressure gages that the reinforcing bars would not interfere with the pressure of the concrete upon the gages.

Apparatus

The apparatus used consited of the same iron rings and the same pressure gages which were used in the laboratory tests; a level rod with a flat piece of sheet iron fastened to the end to provide bearing area, for measuring the heighth of concrete; a stop watch and a whistle. The iron rings were placed in the forms when the forms were built. Two rings were placed in each of the four long posts on one span, and just as near the bottom of the post as was practicable. Since the spandrel posts, floor beams and floor slabs for one span were poured in one day, there was no opportunity to move the rings during the process of pouring and get readings on other posts in that span. By the method outlined, it was possible to get eight gage readings during the pouring of one span.

Materials

The materials used in making the concrete consisted of Owl Portland Cement, and a good grade of washed Wabash River sand and gravel. The tests of the sand and gravel gave the following results:

TABLE I.—SIEVE ANALYSIS OF SAND

Size of Sieve	Weight in Grams of Sand Retained on Sieve	Percentage of Whole Retained on Screen
¼"	0.0	0.0
No. 5	21.1	4.2
" 8	53.5	10.7
" 10	52.5	10.5
" 20	154.6	30.9
" 40	125.0	25.0
" 60	51.2	10.2
" 74	14.7	2.9
" 200	21.0	4.2
Pan	6.8	1.4
	500.4	100.0

Table II.—Sieve Analysis of Gravel

Size of Sieve	Weight in Grams of Sand Retained on Screen	Percentage of Whole Retained on Screen
1.48	0.0	0.0
1.05	480.5	24.0
.742	228.3	11.4
.525	272.5	13.6
.371	200.6	10.0
.263	254.6	12.8
Pan	563.3	28.2
	1999.8	100.0

The proportions of cement, sand, and gravel were 1:2:4. The maximum size of gravel permissible was that which would pass a 1¼-inch screen. A Smith batch mixer was used for mixing the concrete, and an Insley spouting system was used to transport the mixed concrete to its place in the forms. The consistency of the mixture was wet. The rate of mixing was about one batch per minute. It required from 7 to 9 minutes to fill one of the spandrel posts with concrete.

Method of Making Tests

The gages were calibrated both before and after making each series of tests in the manner described previously.

Four men were required for the carrying on of the tests. One to put in place each of the two gages in a column form and to record the pressure readings when the concrete was poured; one to time the pouring of the concrete with a stop watch and blow a whistle as a signal for the gage readings to be taken and the height of concrete to be measured; and one to measure the height of concrete when the signal was given. With the data thus obtained it was possible to determine the rate of pouring, the height of concrete and the pressure on the forms.

Observations During the Tests

The increase of pressure as indicated by the gages was not constant, as one might suppose. The gages indicated an increase of pressure by jumps, as though the aggregate would form an arch across the column form and, giving way suddenly, would cause the gages to show a sudden rise in pressure. It was also noticed that upon the discontinuance of pouring of concrete for a few seconds, the pressure would begin to drop.

There was some leakage of water from the forms but apparently this had no effect on the pressure.

If, after a height of 5 or 6 feet of concrete above the gages had been reached, the pouring was discontinued for a few seconds, it was seldom that the gages would again show an increase in pressure when pouring was resumed. Apparently the concrete had had sufficient time to settle into a stable position and the impact of the new concrete was not sufficient to jar it loose and thus increase the pressure at the gages.

DATA

A total of sixteen gage readings were taken in the field tests. Of these sixteen, nine appeared to be very consistent, and these were used in deducing the results. The other seven gage readings were of such an erratic nature that it was not thought advisable to use them. In some cases no pressure whatever was recorded indicating that there had been some obstruction in front of the diaphragm, while in other cases no pressure was indicated at first, but there would be a sudden rise in pressure reaching very close to the same maximum recorded by the other gage.

While pouring the concrete in the post forms the end of the spout rested on the floor slab forms and the concrete was permitted to drop from this point into the post forms. In falling, the concrete would strike one side of the column before dropping to the bottom. Apparently this had no effect on the gage readings for the long columns, but for the short columns, the concrete dropping near the gage caused an appreciable increase in the pressure.

CONCLUSIONS

The pressure gradually increases with the head until a maximum is reached, after which the pressure falls off. The height at which this maximum pressure occurs depends upon the consistency of the concrete and upon the rate of pouring.

The actual pressures recorded approximate very closely that of a liquid having the same weight as the concrete, or about 145 pounds per square foot per foot of head.

General Conclusions

The results obtained from the field tests agree closely with those secured from the laboratory tests.

Concrete falling against the forms may result in high lateral pressures due to impact.

A value of 145 pounds per square foot per foot of height

would be a rational value for lateral pressure to use in the design of forms.

The results of these tests are not conclusive but it is believed that they are sufficiently consistent and accurate to furnish lateral pressure values which may be used as a basis for the design of forms under average working conditions.

The laboratory tests were carried out by senior civil engineering students under the immediate supervision of Professor A. B. McDaniel and furnished the basis of two baccalaureate theses. The field tests were made by Professor McDaniel and Mr. Garver assisted by two graduate civil engineering students.

Mr. J. J. Jobst, contractor, of Peoria, Illinois, his superintendent, E. C. Miller, and his engineer, F. C. Thorpe, rendered valuable assistance in making the field tests.

FUTURE USE OF WATERWAYS

BY F. H. NEWELL

Professor of Civil Engineering, University of Illinois

To the civil engineer there is no question of internal development which has greater interest from the professional as well as from the civic side than that of the development and use of the inland waterways. Although much has been written on the subject, there has been a tendency to obscure the real points at issue. The reason for this is not difficult to describe since the discussions have been largely from the standpoint not of fact but of political expediency.

The comfort and prosperity of civilized countries is dependent largely upon transportation. With reduction of cost and improved facilities there has resulted a concentration of population so great that any interference with transportation lines means not merely inconvenience but actual suffering. Anything which affects transportation has an immediate interest to a great part of our citizens.

Most of the food stuff and manufactured articles are now transported by railroads. There was a time when waterways were supreme and the location of centers of population was dictated by the existence of navigable rivers or canals. The growth of the railroad systems, however, during the second half of the last century was so great that water transportation not only declined relatively but absolutely and in many localities has

been practically abandoned. There came a time when the rapid growth of the country overtook the capacity of railroads to handle the freight. This and other conditions lead to a consideration by the public as to whether wisdom had been shown in permitting the use of the waterways to decline. Interest in the matter was stimulated by many relative considerations such as the employment of rivers and canals not only for transportation but also for the production of water power. There was also involved the question of the proper protection of rivers from injury by soil washing and by pollution from industrial and domestic waste.

The prime consideration, however, in urging larger development and use of inland waterways is that of reducing the cost of transportation. The cost of moving bulky freight by water is often far less than by land. The claims as to the amount of this saving have been excessive, but are worthy of consideration. More than this, the railroad rates in the past at least have been determined largely by the possibility of water competition. Those localities which can receive freight by water are still favored while the inland points equally accessible by rail but not by water are compelled to pay larger freight rates and thus to make up for losses incurred by the railroads in carrying freight to cities located on waterways.

The action of the railroads in thus discriminating against points away from navigable bodies of water is resented by that part of the public which does not enjoy these privileges. The belief has grown that the railroads are not merely competing with the water lines but have been trying to put them out of business by the improper lowering of competing rates. There are enough true statements of unfair dealings to arouse a strong sentiment against the railroad management, and this in turn has added to the feeling that waterways should be improved at almost any cost.

We may ask how it is that the railroads, starting as they did, as a number of small, feeble lines and entering the transportation field already occupied in a large part by inland waterways, in the course of fifty years or less could practically put the canals and rivers out of business. The reply by "the man on the street" is that the railroads achieved their victory by unfair means and even by conspiracy. There is no doubt but that railroad managers took advantage of every opportunity to cripple their rivals, but it is hardly probable that success would have followed their efforts had there not been certain fundamental conditions which

favored railroad transportation. Stripped of many qualifications, these conditions are as follows:

(a) Greater convenience of flexibility.
(b) Less cost.
(c) Better business management.

Convenience

The physical condition which gives railroads their greatest advantage over waterways is what may be called elasticity, the ability to put a railroad almost anywhere irrespective of topography. It can climb mountain sides or burrow beneath a river or a city. It can branch to every mine, factory, or warehouse. Its units—the carload—are of a convenient size for commercial enterprise; the car can be loaded under cover irrespective of weather and dispatched to the warehouse of the dealer or consumer. This great flexibility permits the railroads to subdivide and branch again and again, crossing or connecting with each other and facilitating the transfer of cars with minimum expense and delay.

In contrast with this the water ways are narrowly limited to the lower lying valleys; only in rare instances can they be continued by canals directly to the mines or factories. The boats or barges which traverse them are of innumerable sizes and shapes; a boat suitable for one river or canal can not venture far into the connecting waters, but must be loaded and unloaded with considerable expenditure of time and labor. Under present conditions waterways can serve but a small portion of the inhabitants of the country, excepting as they are supplemented by railroads.

Cost

The fallacy which is perhaps widest prevalent concerning waterways is the low cost of transportation. As a matter of fact the cost to the public, excepting in a few instances, is often in excess of the cost of transportation by rail. It is true that when the bulky material has once been loaded on board its movement by water to the point of destination is relatively inexpensive, but when we take account of all of the costs of loading and unloading together with a proper interest charge upon the money invested in the waterway and its equipment, also of the depreciation, then the total cost may be several times the amount usually assumed.

Why is it that there has been such a misunderstanding of this simple fact? It is because there has been neglect of considering the true cost and often an unfair comparison or rather an at-

tempt to compare total railroad cost with only a part of the real navigation cost.

To illustrate, in the case of a railroad, investment is made not only in the railroad itself and its equipment, but more than this in the right of way which must be purchased often at large cost and in the grounds and buildings used as terminals and for which the expenditure often exceeds the cost of the main line. All this outlay for lands traversed, for track, cars, and other equipment, stations and warehouses in large cities must pay a profit and interest on the original investment. Taking all of these into account, the cost per ton mile of hauling freight by rail has been estimated to be larger than that by water.

Note carefully however that the cost per ton mile by water as usually given includes only a part of the expense to the public. There is a far larger cost which is not paid directly by the consumer but which is covered by taxes levied directly or indirectly on all tax payers. It is this fact which makes water transportation appear to be cheaper than it is in reality. In one way or another a part of the real cost is concealed. Because a certain proportion of the cost of water transportation can thus be levied upon the public and because the amount thus paid by the public often can be made a matter of private gain it follows that widespread misconception has been encouraged.

To put the matter more plainly, the people of a certain locality urge Congress to appropriate for the improvement of navigation, primarily because the money will be spent in that locality with profits to contractors and more or less incidental gains to local persons. This is a definite and tangible result. The appeal is made to Congress to authorize the expenditure under the plea that lower freight rates to that particular locality can be obtained through an assumed greater economy in water transportation, thus forcing the railroads to reduce their rates correspondingly. It is not shown, however, that this lowering of rates may come about because of the fact that the public directly or indiectly donates a certain amount of money in aiding water transportation and does not ask or expect to receive any interest on the investment. If it did, the total cost of shipping the freight might not be materially reduced.

BUSINESS MANAGEMENT

Preparedness or careful forethought is one of the leading reasons why the railroads have practically put the waterways out of business. The first railway organizations, as separate corporations, were weak and struggling, many of them quickly going into

bankruptcy. They were gradually forced into co-operation and finally into consolidation to bring about greater efficiency and economy. The control of these consolidated small lines necessarily passed into a relatively few hands. The men who come to the front are the product of a lifetime of practical experience in railroad business. They are men picked for their devotion and skill, who give all of their time and energy to the complicated problems and who plan far ahead for the development of business.

In comparison with this attitude has been that held with regard to the waterways. They have come largely under the control of the state or federal government, the plaything of politicians, who have little time or energy to give to the real business and who possess no experience, or if they acquire any, they remain in office too short a time to utilize fully the experience. There can be no comparison in regard to efficiency between the irresponsible shifting oversight given to the canals and the highly efficient, keen business management of the railroads. The public chooses for its managers of the canals men who could never hope to attain any responsible position in a railroad organization.

Other Benefit

The result has been inevitable. The railroads, more flexible, better managed, and more economical in transporting most classes of freight, have so far outdistanced the waterways that the question really resolves itself into one as to whether the indirect benefits which may come from maintenance of waterways are sufficient to justify a part of the cost to the public of utilizing them for the transportation of freight. Some benefit may come from the development of water power. This like the use of the waterways for transportation has undergone a revolution. At one time the industries of the country were largely controlled as regards location by the existence of water power. Mills and manufacturing towns were located near falls on the rivers. The improvement of the steam engine, however, and the fact that it could be located at almost any point, gradually caused the shifting of manufacturing centers from the banks of streams. The improvement of water wheels, however, did not keep pace with the development of the steam engine. At the same time the railroads with their flexibility contributed to the transfer of the manufacturing to points nearer the centers of production of coal, iron ore and cotton, and other raw materials.

With the improvement of electric transmission, however, the water powers have been gradually coming back into favor. The

steam engine has nearly reached its limit of economy, while mechanical ingenuity has achieved striking results in the improvement of the water wheel, electric generator, and transmission lines. The revival of the use of water power may be considered as a prophecy as to what may take place in the revival of the use of the water ways for transportation. The interest of the public in the waterways is thus increased because of the increased benefits which may come from these two lines of effort in putting them to larger use.

FUTURE PROGRESS

One of the most striking indications that engineering skill is coming to the rescue of the waterways is in the recent experience in improved boats or barges. For two generations there has been little, if any, notable progress in ship building for inland waters. The familiar stern wheel steamer has marked the high point of development. There has appeared to be no stimulus toward improvement of the old patterns. We seem to have reached perfection along this line. Also the crude methods of loading and unloading largely by hand have persisted through all the years of change and improvement in mechanical devices. Each steamboat or water transportation line has been operated almost wholly irrespective of all other means of conveying goods. While the railroads have built great terminals with improved machinery and have arranged for through routing, the managers of inland boats have been content to pick up freight along the river bank and after carrying it the required distance drop it again on the bank.

A new era apparently is dawning—one where efforts will be made to catch up with the progress of events and to utilize modern appliances and systems of handling goods. For example, between Kansas City and St. Louis a new freight line has been established with up-to-date terminal facilities and with barges and tow boats radically different from those formerly in use. Out of St. Louis also there is to be put into operation a still more complete barge which has been described as of self-propelled, all-steel construction, to carry 1,600 tons of freight to the Gulf. It is the pioneer of a fleet of 36 vessels which it is expected will be in operation by the spring of 1918. It has four internal combustion engines, each working one propeller of 51 inches diameter. There is no fire on board, the heating and lighting being done with electricity, thus reducing the insurance. The barge is equipped with an electrically operated traveling gantry crane which is capable of extending a boom on either

side of the barge 68 feet and can lift 3 tons at a time. This crane straddles the cargo box and can travel along the barge on a rail for 108 feet.

The cargo box is a steel structure 200 feet long, 40 feet wide, and 12 feet high. Its roof can be removed in its entirety, or in sections, permitting the operators to reach the cargo anywhere. The vessel itself is 240 feet long and can navigate in 3½ feet of water, carrying 500 tons. At 7½ feet draft it will carry 1600 tons. The barge is equipped with an ice plant which gives refrigeration enough to cool a chamber of 6000 cubic feet to a temperature of 31 degrees against an outside temperature of 95 degrees.

The barge is equipped with four watertight and airtight bulkheads, and since the deck is also air and water tight and has no hatches, a puncture of the bottom will not permit the water to enter faster than it can force the air out of an airtight can—the hull. Further, one may, in the pilot house, by turning a switch, start three powerful electric bilge pumps, capable of discharging 800 gallons a minute.

These and similar efforts seem to indicate that progress may be expected in the larger use of inland waterways, but we can hardly look for notable increase until there has been adopted a systematic and business-like policy with regard to the rivers themselves. No one for a moment would have considered entrusting the management of a complicated railroad system to men elected by popular vote or to committees of the legislature. In the case of the waterways, however, this is practically what is done. The whole policy and each considered item of expenditure is subject to the momentary whim of committees of Congress composed of men who are busy in other matters of more immediate interest to themselves. A work started this year may be abondoned next, or its completion delayed until its use has been long outgrown.

It is true that before Congress acts it requires the advice of the Corps of Engineers of the U. S. army, but this is necessarily confined to more or less technical details. It is given also by men who have been educated primarily with a view to military efficiency and who under the present system are frequently shifted from post to post, being able to give relatively little continuous thought to any one large problem. On larger questions of policy and of business judgment, such as is vital to success of railroad enterprise, the engineer officers wisely abstain from interference with the prerogative of Congress.

The present situation with regard to the control of the inland

waterways may be pictured by imagining an equivalent mileage of railroad controlled as to its operation, maintenance, obtaining of business and meeting of exigencies by two independent committees made up of men who have perhaps occasionally traveled over the railroad, but who have never given thought to its finances and business problems. Also who have other engrossing business which demands most of their time and best efforts. Imagine also that the construction, operation, and maintenance officials were educated primarily for some other work and detailed to one piece of railroad or another for short periods, sometimes making plans, at other times building or repairing the roadbed, but liable to be called off to other classes of work. Under such conditions, even with the best intentions, the railroad thus managed must inevitably go into decline as have the inland waterways.

The people of the country are gradually awakening to this condition. We may expect in time the creation of a public sentiment which will put the management of inland waterways into the hands of men who can and will make a life business of it and with such provision that the finances can be handled in a business-like way through the preparation of a regular budget, in contrast with the present method of apportioning money largely by favoritism. There is reason for such optimism in spite of the fact that the present methods have become so deeply ingrained that many good citizens despair of Congress rising above the level of the "pork barrel" and of treating the inland waterways as a resource of the nation. Let us all hope and work toward this desirable end.

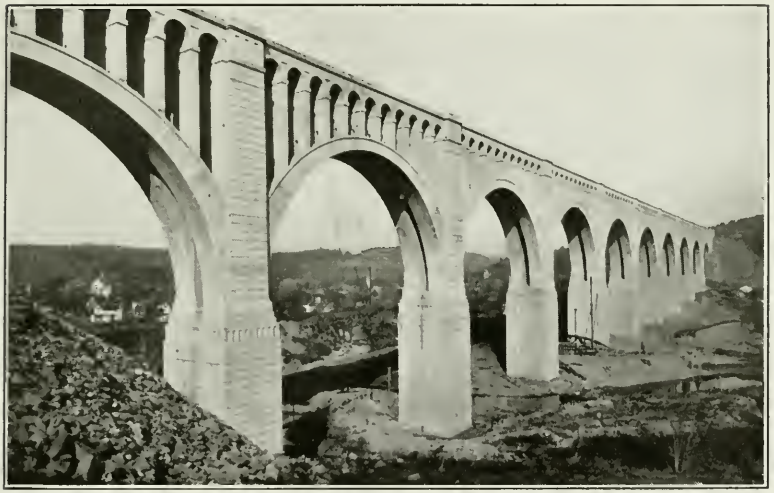
ILLINOIS MEN ON THE TUNKHANNOCK VIADUCT

BY F. H. NEWELL

Professor of Civil Engineering, University of Illinois

Illinois students and engineers may derive inspiration from the achievements of graduates from the Engineering College who have so successfully planned and completed the great Tunkhannock Viaduct, "the ninth wonder of the world". This was lately built by the Delaware, Lackawanna and Western Railroad to reduce the grade and shorten the main line between New York and Buffalo at a cost of over $12,000,000.

The possibility of correcting the alinement and reducing the



grades originated with Mr. Geo. J. Ray, B.S. in C.E. 1898 and C.E. 1910, now Chief Engineer of the railroad. He had the first preliminary surveys made while Division Engineer and later as Chief Engineer carried these surveys to final location. The plans of the structures on the line were prepared in his office and under his personal direction. The construction work was all done under his general supervision.

Other Illinois graduates sharing in the work are as follows:

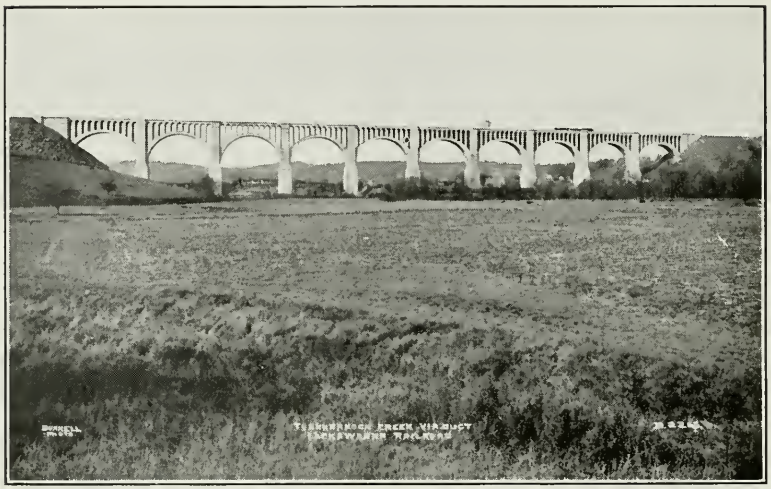
L. L. Tallyn, B.S. in C.E. 1901, Division Engineer of the Scranton Division, had more or less to do with both the preliminary surveys and the final location of this line. Mr. Tallyn

also had direct charge of the erection of all steel bridges, signal bridges, turntables, interlocking towers, and water stations in connection with the work.

J. C. Gilmour, B.S. in C.E. 1905, assisted Mr. Tallyn.

C. W. Simpson, B.S. in C.E. 1904, was Resident Engineer in direct charge of the work on Sections 4 and 5. The tunnel, as well as the Tunkhannock Viaduct, are on Section 5, and, therefore, came under Mr. Simpson's jurisdiction. Mr. Simpson, of course, reported to Mr. Wheaton, Engineer of Construction, in charge of the entire cut-off.

B. T. Anderson, B.S. in E.E. 1907, Assistant Signal Engineer,



had to do with the preparation of the plans for the interlocking and automatic signals in connection with the work.

T. H. Trams, B.S. in C.E. 1907, was a concrete inspector on the Tunkhannock Viaduct during the early stages of the construction.

Lincoln Bush, B.S. in C.E. 1888, formerly Chief Engineer of the Lackawanna, was connected with the construction work on Section 8, on which the Martins Creek Viaduct is located, as a member of the F. M. Talbot Company who did the work on that section. Again, the firm of Flickwir & Bush was incorporated for the purpose of building the Tunkhannock Viaduct. The F. M. Talbot Company, with which Mr. Bush is associated as Consulting Engineer, combined with Mr. Flickwir, and this company under the name of Flickwir and Bush, Inc., carried out the work.

The cut-off or replacement line is nearly 40 miles long and saves 3.6 miles in distance, reducing the maximum grades from

1.23% to 0.68%. Old grade crossings to the number of 22 have been eliminated. The changes were made possible by means of heavy cuts and fills and by enormous viaducts, a work impossible in the early days when the road was built. The earth excavation amounted to over 5,000,000 cubic yards and the rock to over 7,600,000 cubic yards.

The most striking feature of the new line is the viaduct, the largest concrete bridge yet built. It consists of ten spans of 180 feet and two of 100 feet. The maximum height is 240 feet.

Although the distance saved on the through line is apparently small, yet the modern method of operation of trains is such that the new cut-off will pay for itself. It reduces running time on every passenger train between the east and west by full 20 minutes, while each freight train will save an hour on its schedule. In other words, freight trains which formery required five engines can on this cut-off be moved at the same rate of speed by two. As shown in the views, the concrete arches which carry the Lackawanna trains high above the valley are things of beauty as well as of utility. All of the foundations are carried to rock, two of the piers requiring an excavation of 95 feet in depth.

METHODS OF MAKING DRAINAGE SURVEYS

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It has been said that the ideal surveyor is he who does his work just accurately enough for the purpose in hand without a waste of time and money. To fulfill this specification, a surveyor, before starting any survey, must ask himself the questions: What are the purposes of this survey; and what use is to be made of the distances, angles, and elevations that I am about to measure? It is only after these questions have been answered satisfactorily, that the most economical and efficient methods of making the survey can be determined.

The purpose of a drainage survey of swamp and overflow lands is to obtain data from which it can be determined whether or not the project is practicable and profitable; and, if so, to determine the location of levees and of main and of lateral ditches, to make an estimate of the cost, and to determine an equitable distribution of the cost among the land-owners benefited by the improvement.

To obtain this information, a map of the area subject to overflow must be made, which shows the courses of all streams, the boundaries of the district or districts, the boundaries and acreage of each tract of land, the swamps, the high ground, the land under cultivation, the forest areas, and all the works of man, such as railroads, highways, bridges, and existing levees and ditches. There must also be obtained the high water marks, the flood limits, and the maximum flood discharge of the main stream and its chief tributaries.

The surveys that are necessary to obtain this information may be divided into four divisions: the surveys (1) for horizontal control, (2) for vertical control, (3) for topography and details, and (4) for hydrographic data. Drainage surveys will be discussed under these four headings.

1. *Surveys for the Horizontal Control*

In Illinois, the U. S. Army Engineers have surveyed the valley of the Illinois River in connection with the Lakes-to-Gulf deep-waterway project; the Mississippi River Commission has surveyed the lands along the Mississippi River; the State Geological

Survey has made drainage surveys of the overflow lands along the Kaskasia, Big Muddy, Embarrass, Spoon and Pecotonica Rivers; the Drainage Investigation Office of the Department of Agriculture has surveyed the valleys of the Little Wabash and the Skillet Fork; and a great many smaller areas have been surveyed by private engineers in various parts of the state.

In the survey of the Illinois River which was completed in 1905, the horizontal control was obtained by secondary and tertiary triangulation, starting from the secondary triangulation system of the Mississippi River Commission and connecting with the "east base" and "middle base" triangulation stations of the primary triangulation system of the U. S. Lake Survey. This method gives a very accurate horizontal control, but as it is applicable only to very extensive government surveys, it is not a representative method.

The work of the State Geological Survey was done very carefully and accurately. The horizontal control used was the primary traverse transit lines of the U. S. Geological Survey. With these lines for a primary control, a secondary control was obtained by plane-table buggy-traverses which were run along the first ridge road on each side of the river and along other roads when necessary. These lines were tied together and checked by similar lines along the cross roads, and where the cross roads were too far apart, lines were run from stations on the ridge roads to the river, where points were established, which were later tied-to by the stadia traverse of the river. Although the buggy-traverse method is usually considered inaccurate, yet these surveys proved that it was satisfactory for the scale to which the map was platted, which was 1 in. = 2000 ft.

The surveys by the Drainage Investigations Office were made less accurately but more economically than those made by the Geological Survey. The horizontal control consisted of a transit and stadia traverse along or near the bank of the river, and the course of the stream was located by coordinates from this line.

In a number of surveys of smaller areas than those which have been cited along the Illinois and Mississippi Rivers, the horizontal control used was a transit and tape traverse running approximately through the center of the district and parallel to the general course of the stream. Transit stations were established along this line at its intersections with section and quarter-section lines. Starting from these points, transit and stadia traverse lines were run on each side of the base line along the section and quarter-section lines to the limits of the lands subject to overflow; and thence along the overflow line to a similar point pre-

viously established one half mile away. This method is a most efficient one for the comparatively smaller areas.

The method that is now beng used by the State Reclamation Department of Texas is somewhat similar to that used by the Illinois State Geological Survey. The horizontal control is obtained by a primary traverse starting from a geodetic point previously established by triangulation or astronomy to a similar point of closing; or the traverse is returned as a closed circuit to end upon the point of beginning. The lines as a rule follow a central route through the flood plain. The angles of the primary traverse are measured to 30″ and the distances are measured with a 300-ft. steel tape and checked for blunders by stadia measurements. At intervals of about one mile along the traverse line, 4-inch iron pipe are set, which project about six inches from the ground. The tops of the pipes are covered with a brass cap whose center marks the precise point and upon which is stamped the elevation of the point and the seal of the State. The average cost of these traverses has been about $10.50 a mile.

In states where the land was originally surveyed by the U. S. Land Office, the section and township lines are frequently considered as adequate horizontal control for the average drainage survey. These lines are platted to the desired scale from data of the original land surveys, and the location of highways and railroads is obtained from county atlasses and railroad right-of-way maps. This method of obtaining a horizontal control was used by the Drainage Investigations Office of the U. S. Department of Agriculture in making surveys in 1912 of the Cypress Creek Drainage District, Arkansas; and in 1913 of the lands along the Big Black River in Mississippi. And the same organization in making a survey in 1912 of Jefferson County, Texas, where the rectangular system of surveying does not hold, used as a horizontal control the lines taken from a War Department Map, a Coast and Geodetic Map, the county surveyor's maps, and the right-of-way maps of the Southern Pacific Railroad. Again in 1912, in making drainage survey of the swamps in Hampton and Jasper Counties, South Carolina, the Drainage Investigations Office used as a horizontal control, compass and stadia traverses along all the roads of the district. While this method of obtaining a horizontal control is not approved of by many drainage engineers, yet in these cases it served the purpose admirably, and considering the area covered and the cost of a more accurate survey, it was undoubtedly the proper one to use.

In the instances that have been cited, the methods have varied between the two extremes. From the most accurate, the triangu-

lation system, to the least accurate, the compass and stadia traverse. It would seem that all of these could not be efficient methods; the explanation lies in the fact that the purposes of the various surveys were somewhat different. In the survey of the Illinois River, an accurate map was desired for all the purposes for which maps are used, and the drainage of the overflow land was only one of the purposes; hence, the triangulation system of control was employed.

Likewise the work of the State Geological Survey was to serve a double purpose, as the data will be used by the U. S. G. S. in the preparation of their quadrangle maps.

It is only in the other cases that have been cited that the surveys were made for drainage purposes primarily. And in such surveys, the horizontal control is not the most important part of the work; and in most cases, small error in the measurements of distances and angles will not appreciably affect the value of the survey, or the success of the project itself.

In general, the lines of the horizontal control should be run with a transit, using either the direct, or the azimuth method, and the measurements should be made with a steel tape; but the writer would like to call attention to several important surveys—not drainage surveys—in which the distances were obtained by means of the stadia.

1. St. Louis Survey — 22 miles long — error, 1 :930.
2. Idaho Boundary Survey — 65 miles long — error, 1 :2500.
3. Mexican Boundary Survey — 12 miles long — error, 1 :28500.
4. Mexican Boundary Survey — 61 miles long — error, 1 :1116.
5. Mexican Boundary Survey — 670 miles long — error, 1 :2200.
6. Mille Lac Lake — 73 miles long — error, 1 :2160.

If results as accurate as these could be obtained, the stadia could be used in all drainage surveys for measuring the lines of the horizontal control. However, results as these could not be expected from the average instrument-man, who as a general thing has a rather superficial knowledge of the theory and use of the stadia.

2. *Surveys for Vertical Control*

In practically all the drainage surveys that have been made, the vertical control consists of lines of spirit levels along the lines of horizontal control. In the surveys of the State Geological Survey, the primary levels of the U. S. Geological Survey were used

as a base, from which spirit levels were run along the lines of the buggy traverse. The level work was so planned that the lines to be run later by the stadia would not have to be carried more than two miles without a check. Substantial bench marks were established at quarter-mile intervals, approximately.

Primary levels are used also by the state of Texas in its reclamation surveys. The levels are run along the primary traverse lines and permanent bench marks are established about one mile apart. The instruments used are 22-inch Wye levels equipped with stadia hairs. While in use the level is protected from the direct rays of the sun by means of a large umbrella and levels are run only when the atmospheric conditions are favorable. The lengths of fore and back sights are equalized to avoid accumulative instrumental error, and the elevations are corrected for the earth's curvature. Both the levelman and the rodman are required to keep notes, and the figures compared after each reading. The allowable error is $.05\sqrt{}$ Distance in miles, and as would be expected from the precautions taken, no difficulty has been experienced in keeping well within these limits. The average speed is about four miles a day, at a cost of $5.50 a mile.

In those cases where the U. S. Land Surveys serve as horizontal control, the vertical control is obtained by lines of levels along the railroads, and bench marks are placed usually on the mile posts. These levels are carefully checked. From the bench marks thus established, lines of levels are run across the country at intervals of one mile or less, and approximately east and west or north and south. Roads and fence line are followed for convenience. Tie lines are run perpendicular to the cross lines in order to determine additional elevations and to check the work.

For the average drainage survey, the most efficient method for securing vertical control is by a line of spirit levels run and checked with an engineer's level along the important lines of the horizontal control. Along lines of secondary importance, the levels may be carried with the transit at the time the secondary control lines are established.

In making drainage surveys the most important part of the work is the leveling. It is essential to the success of the project that the correct elevations of the depressions to be drained are obtained. From the elevations obtained in the survey, the grade and depth of the ditches are planned, and if the elevations are incorrect, the plans will be incorrect, and the depression will be drained only in part. Since this is true the levels along the lines of the horizontal control must always be checked. Transit level-

ing must not be used for the important lines, and may be used only along the lines of secondary importance only when they are short.

If we assume that, observing certain precautions, the accumulative error in a line of wye levels will not exceed .05 $\sqrt{}$ Distance in miles, then observing the same precautions with a line run with a transit, we should not expect to check closer than about .12 $\sqrt{}$ Distance in miles. Or in other words, levels runs with a transit will be approximately ⅓ as accurate as levels run with a wye level.

4. *Surveys For Topography and Details.*

The topography and details are located by either the transit and stadia or the plane-table and stadia method. Each of these methods has its advantages. The transit is lighter and more easily and quickly set-up and manipulated by the average instrument-man; its telescope is farther from the ground and overlooks more of the vegetation than does the plane table. On the other hand, with the plane table, the data are platted directly on the map, which eliminates note-keeping, and the contours may be sketched in with fewer controlling points than in the case of the transit, where the field data is platted in the office by a draftsman who possibly never saw the land whose relief he is trying to show. The plane table is particularly applicable to large areas which are usually platted to a small scale.

A third method which combines the good points of each of these, consists of taking the data with a transit, but instead of recording it in a note-book, it is platted directly on a field map which is fastened to a portable drafting board, which is either supported on a tripod or suspended from the draftsman by straps across the shoulders and around the waist.

First of all the main stream and its tributaries must be located. This is done by traverses run along or near the banks from which the stream is located by perpendicular offsets or by azimuth and distance. All sloughs, ponds, and marshes must be meandered, so that the lands continuously submerged or which agricultural purposes may be divided from those which are not low enough to be valueless for such purposes. At the same time that these meanders are run, elevations must be obtained of the lowest points of all sloughs, ponds, and other depressions, so that the ditches can be so located and of such a grade as to drain all such places.

Throughout the area, sufficient readings must be taken so that accurate contours can be drawn. Where the bottoms are

covered with dense woods, the topographic sketching is by far the most difficult and important part of the work. Stadia lines are started from convenient bench marks and zig-zag through the bottoms through the openings of greatest length in the general direction of the traverse. The meandering traverse line is the most reliable method for finding isolated lakes, marshes, and hills hidden by the woods.

In open country, the traverse lines are most conveniently run along the section and quarter-section lines, and traverse stations are located at the quarter-quarter-section corners, so that the instrument-man can more readily assist in the search for the monuments at these points. This method has the advantage that the elevations are taken at the points where they are most needed, as it is usually along the section and quarter-section lines that the ditches are constructed. It frequently happens that all the desired elevations and details can not be taken from the traverses thus run and spur traverses of one or two stations will have to be run in order that these data may be obtained.

In taking the topography, the topographer must always bear in mind that the purpose of the project is to drain the land, and that the principal purpose of the survey is to obtain the location and elevations of the lowest lands to be drained, and that the surveys for horizontal and vertical control have been made expressly to enable him to determine the correct locations and elevations of these points. I mention this fact because surveyors frequently become so interested in the work that they are doing as a problem in surveying that they lose sight of the main objects of the survey, and spent more time in locating certain details than the importance of the details justify.

4. *Surveys For Hydrography.*

In order that the levees on the opposite sides of the stream channel may be far enough apart and high enough so that maximum floods may be carried between them, it is necessary to take some hydraulic measurements in the field to obtain the maximum discharge. A section of the stream as long as possible is selected where the channel and floodway are comparatively straight and reasonably uniform. About the middle of the section a cross-section is taken. The elevation of the water surface is carefully noted, and the area in square feet is determined by soundings at regular intervals across the stream. The velocity of the water is then measured with a current meter. Meter readings are usually taken at intervals of about ten feet and at points .2 and .8 of the depth below the surface of the water. The mean velocity

of each 10-ft. section is then the average of the two meter readings. The discharge of each section is then obtained by multiplying the average velocity of each section by the area of the section. The sum of these several products is the total discharge of the stream, which divided by the area of the entire stream gives the mean velocity of the stream. If the stream is too deep and too swift to admit of wading, the meter readings may be obtained from a bridge, from a cableway suspended across the stream, from a ferry boat, or a captive skiff. This gauging of the stream should be done when a flood is actually passing in the stream. By a number of gaugings taken at different stages of the river, a rating curve may be drawn which will show the general course of the discharge curve. From this curve together with the elevation of the observed high-water marks, the maximum discharge of the stream may be determined with reasonable accuracy.

EMPLOYMENT AFTER COMMENCEMENT

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I have been asked to contribute a brief article to the Civil Engineering Number of THE TECHNOGRAPH. At this season of the year the teacher naturally attempts to make an appraisal of the capacities and tendencies of those who are shortly to graduate; and his sympathy goes out to them as they consider ways and means of securing professional employment after commencement day.

I assume the privileges of my age and position, and offer some hints with the hope that they may possibly be helpful to the senior as he goes forth into a busy world.

In the main, during all of your life you have been working under direction. Your lessons have been assigned, your program has been arranged, you have been held to definite tasks, you have been compelled to do your work in a particular way, and you have not had much opportunity to show your individuality. In most respects you have been regarded as a boy. But from now on most of this will be changed. You will be treated as a man, you will choose where, when, and for whom you will labor. Thus far in your life, the chief object of those who have affected your life most was to serve you, and your sole purpose has been to receive; but from now on, the chief object of your life must

be to serve others. Heretofore, your chief ambition was to know; but from now on your duty will be to do. The change of attitude from being continually expected to receive, to one in which you are expected to give, is very great; and not unlikely will cause you to make some unconscious mistakes. For example, if a few weeks or months from now your work has ceased to be instructive, you may not ask your employers to change it solely to enable you to secure more valuable experience, for it is your duty to put his interests above your own.

May I give a homely illustration of the principles I am trying to present? A year or two ago through the employment bureau I secured a student, a young man, to clean my automobile and do a few other chores. One morning I got up early, and was writing at my desk at 5 o'clock when the door bell rang. I went to the door and found a young man who said the student who regularly came to work on Saturday morning desired to go on an educational excursion, and had sent him instead. The substitute asked if I would show him about the work; and explained that he had come earlier than the time assigned for the regular man, because he himself desired to meet an appointment in a distant part of the city at 8 o'clock. Incidentally I may say that his early call waked up members of my family that had a right to sleep longer; but he seemed to be unconscious of this. I hunted up the appliances and showed the substitute what was to be done, even though it took 25 minutes of my time to explain to him how to do an hour's work. Further, leaving my desk so disturbed my train of thought that in the remaining half-hour available for my work, I was unable to recover the thread of my subject, and virtually lost an hour of my time by the transaction. Both young men are really competent students, and both are right minded and earnest; but both overlooked the fact that our only relation was that of employer and employee. Neither were in my department, or even in the College of Engineering. The regular at his next visit made no explanation or offered any excuse for his absence. Neither young man seemed to be conscious that he had in any way transgressed business courtesy. Each apparently assumed that his own interests were of greater importance to me than my own. The point I want to emphasize is that both of these young men had the wrong point of view of their relations to their employer. In some respects this example is exceptional, but in the main it is representative, as all who employ students have had somewhat similar experiences.

Unfortunately, this example is representative of occurrences in the practical experience of young engineering graduates. Here

is a recent example of one of my own students. He was quite a competent student, and had asked me to assist him in securing work which would be instructive and in which there was a good chance for advancement. I recommended him to one of my friends who was doing a rather unusual line of very interesting and instructive work. The student went to work shortly after commencement at $60.00 per month. A little more than a month later, he wrote to me that he had quit because he had been refused an increase in pay. I knew the employer quite well, and shortly thereafter went to see him. He explained that the young man was a bright fellow; but on account of the nature of the work, the supervision required was considerable, and the young man did not really earn more than half of his salary. When I carried this information to the young man, he was incensed and denounced the employer as a skinflint. When I explained some things I knew about the employer and what he was doing for some of his employees, and particularly that for a number of years he had always had one or more young men to whom he was giving an education, the young graduate changed his mind. Within a year I had two letters from him begging me to help him to get back with his former employer at any price; but naturally enough the employer refused to receive him on any terms.

It is said that some employers refuse to have anything to do with college graduates until after they have been out a year or two, because the young graduate so frequently fails to recognize the difference between the relationships and the conditions in college and those in business. Happily there are not many such employers. Most business men are sympathetic, charitable, and patient with the young man, and have confidence in his right intentions and ultimate success.

However, the young graduate should carefully discriminate the difference in relationship to them of the professor and the employer, and should consider the difference between their relationship to the university and that to the company. Further, the employer is likely to be more exacting as to attendance and promptness, and to demand more as to compliance with instructions than the college professor; and it is usually necessary that he should be more exacting. Employers and clients want results, not excuses.

These matters may seem to be small, but a proper understanding of them may save you from embarrassment and prevent you from unconsciously doing damage to your own reputation.

WIND STRESSES IN THE STEEL FRAMES OF OFFICE BUILDINGS

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1. Preliminary.—The increase in the price of land in large cities has made it necessary to build high buildings in order to get a large rentable floor space on a small parcel of land. The type of building generally used is known as the steel-skeleton building. In this type of building the live and dead loads, including the weight of the walls, are carried by a system of beams and girders to columns and are carried by the columns to the footings.

In high buildings the horizontal shear due to the wind load is very large; and, since it is usually impracticable to put diagonal braces between the columns, it is customary to make the steel frame rigid enough to resist the horizontal shear by virtue of the stiffness of the columns and girders.

2. Present Methods of Calculating Wind Stresses In the Steel Frames of Office Buildings.—The exact determination of the stresses in a steel bent due to a horizontal shear is very complicated. While some effort has been made to devise an exact analysis of the wind stresses in the steel frames of office buildings,* designers of the building for the most part, have been content to use approximate methods.

Four approximate methods have been used. For convenience in reference these will be designated as Method I, Method II, Method III, and Method IV, respectively. Mr. R. Fleming presented the first three methods in Engineering News.* These methods, as applied to a building in which all columns of a story have the same section, are based upon the following assumptions:

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*Wind Stresses in the Frames of Office Buildings, by Albert Smith, Journal Western Society of Engineers, Vol. XX, No. 4, p. 341.

Stresses in Tall Buildings, by Cyrus A. Melick. Bulletin No. 8, College of Engineering, University of Ohio.

The Theory of Frameworks with Rectangular Panels and Its Application to Buildings which Have to Resist Wind, by Ernst F. Jonson, Tran. Am. Soc. C. E., Vol. 55, p. 413.

*Wind Bracking without Diagonals for Steel-Frame Office Buildings, Engineering News, March 13, 1913.

Assumptions in Method I

1. A bent of a frame acts as a cantilever.
2. The point of contra-flexure of each column is at mid-height of the story.
3. The point of contra-flexure of each girder is at its mid-length.
4. The direct stress in a column is directly proportional to the distance from the column to the neutral axis of the bent.

Assumptions in Method II

1. A bent of a frame acts as a series of portals.
2. The point of contra-flexure of each column is at mid-height of the story.
3. The shear is the same on all columns of a story.
4. Each pair of adjacent columns of a bent acts as a portal, and each interior column is a member of two adjacent portals. The direct stress in an interior column, when the column is considered as a member of the portal on one side, is of opposite sign from the direct stress in the same column when considered as a member of the portal on the opposite side and the resultant direct stress is equal to zero.

Assumptions in Method III

1. A bent of a frame acts as a continuous portal.
2. The point of contra-flexure of each girder is at its mid-height of the story.
3. The direct stress in a column is directly proportional to the distance from the column to the neutral axis of the bent.
4. The shear is the same on all columns of a story.

Professor Albert Smith, in a paper before the Western Society of Engineers, describes a method which he has used in his classes in Structural Engineering at Purdue University. This method is here designated as Method IV:

Assumptions in Method IV

1. The point of contra-flexure of each column is at mid-height of the story.
2. The point of contra-flexure of each girder is at its mid-length.
3. The shears on the internal columns are equal and the shear on each external column is equal to one-half of the shear on an interior column.

If all of the assumptions of any one of these methods are ac-

cepted, the stresses in a frame may be determined by applying the fundamental equations of static equilibrium.

The four approximate methods described above are all short and simple and, when any one of them is considered by itself, the assumptions upon which it is based seem reasonable. It is an unfortunate fact, however, that if the four methods are applied to the same frame, the results obtained by the four methods are radically different. Furthermore in the absence of an accurate method to be used as a standard of comparison, it was impossible to judge of the relative accuracy of the approximate methods.

The method described in this article, known as the slope-deflection method, devised jointly by the writer and Mr. G. A. Maney,* is offered as a standard by means of which the accuracy of the approximate methods can be measured.

3. Outline of the Proposed Method.—In making an analysis of the stresses, the writer made certain assumptions and applied certain fundamental principles of mechanics and obtained equations from which the stresses in a frame can be determined. The assumptions which have been made are stated in Section 4 and the fundamental equation is given in Section 6.

It can be proven that the moment at an end of a member of a frame is a function of the changes in the slopes of the tangents to the elastic curve of the member at its end and of the deflection of one end of the member relative to the other end (see equation A, Section 6).

In the strained position, all the columns and girders which intersect at one point have been subjected to the same change in slope (see assumption 1); the vertical deflections of the ends of all girders are equal to zero; and the horizontal deflections of the tops of all columns of a story are equal (see assumption 2).

Consider any story of a bent. Take the point of intersection of the neutral axes of a column and a girder as a free body. It is in equilibrium under the action of the moments at the extremities of the columns and girders which intersect at the point. Each of the moments may be expressed in terms of the changes in the slopes at the extremities of the member, and the deflection of one end of the member relative to the other. A moment equation can therefore be written for each point where the columns and girders intersect, and the only unknown quantities will be the changes in the slopes at the extremities of the columns and the horizontal deflections of the columns in a story.

If all the columns of a story be taken together as a free body, the sum of the moments at the two extremities of all the columns

*See Bulletin No. 80, Engineering Experiment Station, U. of I.

will be balanced by a couple whose moment is equal to the total shear on the story multiplied by the story height. The shear and the height of the story are known, and the moments in the columns can be expressed in terms of the slopes and the deflections at their extremities the same as in the previous equations. It is therefore possible to write as many equations for each story as there are columns in the story, plus one. As the unknown quantities in these equations are the changes in the slopes at the extremities of the columns and the deflection in a story common to all columns, there are as many equations per story as there are unknowns. By solving these equations the slopes and the deflections can be determined. Knowing the slopes and the deflections, the moments can be computed.

The product of the sheer on a member and the length of the member is equal to the algebraic sum of the moments at the extremities of the member. Since the moments and the length of the member are known, the shear can be computed.

With the shears in the girders known, the direct stress in any column can be determined by taking the column as a free body and equating the sum of the vertical forces to zero.

4. Statement of Assumptions.—The proposed analysis is based upon the following assumptions:

1. The connections between the columns and girders are perfectly rigid.

2. The change in the length of a member due to the direct stress is equal to zero.

3. The length of a girder is the distance between the neutral axes of the columns which it connects and the length of a column is the distance between the neutral axes of the girders which it connects.

4. The deflection of a member due to internal shearing stresses is equal to zero.

5. The wind load is resisted entirely by the steel frame.

5. Fundamental Proposition.—The fundamental equation used in this analysis is based upon the following proposition:

When a member is subjected to flexure, the deflection of any point in the neutral axis from the tangent to the elastic curve at any point is equal to the moment of the area of the $\frac{M}{E\ I}$ diagram for the portion of the member between the two points, about the point where the deflection is measured.

6. Fundamental Equation.—By applying the fundamental proposition given in the preceding section, the following equation

for the moment at the end of a member AB restrained at the ends and carrying no intermediate external loads, can be derived:

$$M_{AB} = 2\,E\,K\,(2\,\Theta_A + \Theta_B - 3\,R) \quad \text{A}$$

In equation A.

E = the modulus of elasticity of the material.[1]

K = ratio of the moment of inertia to the length of the member.

R = deflection of the member divided by its length.

Θ_A = change in the slope of the tangent to the elastic curve at A.

Θ_B = change in the slope of the tangent to the elastic curve at B.

M_{AB} = moment at end A of member AB.

The signs of the quantities are determined by the following rules:

The change in the slope, or the angular deformation, is positive (+) when the tangent to the elastic curve of the member is turned in a clockwise direction.

Distances and deflections are positive when they are measured in the same direction from the base line as are positive slopes.

If the internal stress couple acting on the portion of the member considered tends to produce a clockwise rotation the moment is positive.(+).

Equation (A) is general and may be applied to any length of any member in bending provided the length considered has no intermediate external force applied to it. That is, one or more of the quantities Θ_A, Θ_B, and d may be negative and equation (A) will still give the moment at the point A in both magnitude and sign. Equation (A) is the fundamental equation upon which the analysis is based. Equation (A) may be expressed as follows:

The moment at the end of any member is equal to 2 E K times the quantity: Two times the change in the slope at the near end plus the change in the slope at the far end minus three times the deflection divided by the length.

7. Application of Fundamental Equations to a Steel Frame.—If equation A is applied successively to the columns and girders of a frame as outlined in Section 3, equations can be written equal in number to the unknows which they contain. The equations can, therefore, be solved and the stresses in the members determined. These stresses, except as affected by possible errors in the original assumptions, will be accurate and can be used to determine the relative accuracy of the approximate methods.

8. Comparison of the Approximate Methods with the Slope-Deflection Method.—The stresses were determined in a number

of bents having different proportions, by the slope-deflection and by the approximate methods. From the results of the calculations the writer made the following conclusions:

a. Methods II and III of Section 2 are so inaccurate that they should never be used; I and IV are quite accurate in some cases, but they may give results which are seriously in error.

b. The method outlined and designated as the slope-deflection method, contains no approximations except those in the assumptions.

c. While the slope-deflection method is long, it could be used in the actual design of a building; but it has its greatest value as a standard by means of which the accuracy of the approximate methods may be determined.

If, because of errors in the distribution of wind stresses, a column or girder is over-stressed in bending, the danger of failure of the structure as a whole is not as great as it is in the case of a member subjected to axial load. For if a column is subjected to a greater shear due to the wind load than the calculations indicate, the column instead of failing, will deflect and a part of the load will be automatically transferred to the other columns. The exact determination of the bending stresses in the columns and girders due to the wind load is not therefore as important as the exact determination of axial dead and live load stresses. It is also contended that, since the wind load itself is so uncertain, the exact determination of the stresses due to an arbitrarily fixed wind load is not especially desirable.

While admitting that there is considerable force to the above arguments, the writer contends that if a short and simple method can be devised that is accurate, the accurate determination of stresses due to arbitrarily fixed wind loads is important. For even though a column which is overstressed has part of its load automatically transferred to the other columns, it is nevertheless overstressed. That is, its factor of safety will be smaller than the factors of safety of the other columns. If the factors of safety for the columns vary, either some of them are dangerously weak or others are needlessly strong. Furthermore, even though the wind load is uncertain in amount, it is desirable as far as possible, that each column be equally liable to failure. That is, while there may be a question as to the total amount of material that is added to resist the wind load, it is desirable that what material is added be distributed so that it will do the most good.

If engineers are to seriously claim membership in a learned profession they must do their work so as to combine minimum cost with the greatest safety. Good engineering is an insurance against failure, whereas wasted material is a tribute to ignorance.

THE NEED OF A NEW METHOD OF SMOKE INSPECTION

BY C. S. SALE

Assistant Director of Engineering Experiment Station, University of Illinois

Although bituminous coal has been used as fuel for more than six centuries and the smoke and soot arising from its combustion have been, through all this period, regarded as objectionable, it was not until the end of the Nineteenth Century that any satisfactory method of measuring or evaluating smoke emissions was developed. Then, in the early nineties, Professor Ringelmann of Paris, France, perfected a simple and easily duplicated standard of measurement which has been known as the Ringelmann scale. Briefly, it consists of six areas of equal size which may be drawn on white paper or cardboard. The charts are numbered from 0 to 5, inclusive. The first area presents a white surface only; the second is subdivided into small squares by crossed lines, the width of the lines and their spacings being such as to blacken 20 per cent of the surface; the third, fourth, and fifth areas are similarly cross-hatched so that 40, 60, and 80 per cent, respectively, of their surfaces are blackened; the sixth area is entirely black. When this scale of charts is placed at sufficient distance from the eye to cause the definition of the lines to be lost so that the intermediate areas between the white and black charts present only varying shades of gray, it provides a standard by means of which visible smoke emissions may be compared and evaluated. For instance, if the smoke under observation, when compared with the Ringelmann scale, matches the first shaded area its density is recorded as 20 per cent; if it matches the second shaded area its density is 40 per cent. If the smoke discharged is black and matches the last area on the chart it is recorded as No. 5 or 100 per cent smoke. A simple method of combining large numbers of observations has been developed and the use of the Ringelmann scale has become almost universal in municipal departments of smoke inspection in the United States and Europe.

Special instruments designed for use in making observations of smoke are also available. These usually consist of a telescope in which are mounted several flat lenses of varying shades intended to correspond to the different shades of the Ringelmann scale. A lens of any desired shade may be adjusted to

cover a portion of the field of vision. By selecting a lens which matches the shade of the smoke under observation, the density may be read from a scale accompanying the instrument. Satisfactory observations by means of such devices are difficult owing to the necessity of securing a clear background for the shaded lens which covers a part of the field of vision, while the smoke is viewed simultaneously through the remaining or exposed portion of the field.

It is to be noted that the Ringelmann scale and other devices designed for smoke observations are useful only for giving a numerical value to the shade or density of the smoke as it appears to the eye. They have been designed and used on the theory that smoke emissions are objectionable in proportion to the extent to which they are visible. In further emphasis of this theory, the smoke abatement ordinances of various cities relate to smoke in its visible aspect only. The ordinances of certain cities prohibit "dense smoke"; in the case of other cities it is "black smoke", "dark gray", or "dense gray smoke". In only a few cities have the ordinances been drawn with regard to the solid constituents of smoke such as soot and ash, which are often not visible at the distance at which observations are normally made, or the gaseous constituents, such as the carbon and sulphur compounds, which under certain conditions are harmful to animal and vegetable life.

But even for observations to determine the visible density of smoke the Ringelmann scale and other devices designed for the same purpose are deficient in that they do not take account of the volume of smoke discharged. For instance, a stream of No. 1, or 20 per cent smoke, issuing from a stack two feet in diameter, would, theoretically, appear as No. 2, or 40 per cent, if issuing in the same degree of concentration from a stack four feet in diameter, although its volume would have increased in proportion to the increase in the area of the stack, or in this case, four times. The element of distance also has an influence upon the accuracy of visual observations.

The recent extensive investigation conducted in Chicago under the direction of a special Committee of the Chicago Association of Commerce disclosed the fact that there exists no relation between the visible density of smoke emissions and the quantity of dust, soot, and ash discharged. In some cases stacks which appeared clear when compared with the Ringelmann scale were found to be discharging in the form of finely divided solid particles and soot as much as 2½ per cent of the fuel fired; in other cases stack discharges rated by the Ringelmann method

as 25 or 30 per cent smoke were found to be giving off less than one per cent of the fuel in the form of solids. The so-called low pressure heating plants in Chicago, including the domestic fires, were charged, according to the Ringelmann method, with only four per cent of the smoke of the city, while the tests to determine the amount of solids discharged by these plants disclosed the fact that they are responsible for nearly nine per cent of the total for all services and for nearly 57 per cent of the total soot or tarry materials condensed from the distillates of fuel, discharged into the atmosphere in the smoke of all services.

Similarly when an attempt is made to compare the relative importance of smoke discharges on the two bases of visible smoke and the gaseous products of combustion, the same discrepancies appear.

The need for a new standard or method for smoke observation suitable for general use is great, but the problem is by no means simple. A satisfactory standard primarily must be simple and easy to apply and it must take account not only of the volume of discharge, but also of the character of it. The public demand for smoke abatement in the large cities is constantly increasing and it must be met by a procedure which not only strikes at the real sources of atmosphere pollution, but which is fair alike to each of the various fuel consuming agencies involved.

THE 1916 CIVIL ENGINEERING INSPECTION TRIP

J. C. STIRTON, '16

Probably the most striking fact brought out during the Civil Engineering Inspection Trip was this: engineers of today are willing and competent to solve problems of any magnitude. At every place visited utter disregard for the size of the difficulties met with was apparent. In order to produce steel at Gary, coal from Virginia and iron ore from Duluth are used. The barrier of distance is being successfully overcome there. In order to obtain the large output necessary to meet with the demand, a vast sum of money had to be invested in equipment. The engineers and financiers co-operated, and due to their confidence in their ability to carry out well-laid plans, they had the courage to go

ahead and establish one of the greatest industrial plants in the world. Thus, the obstacle of expense was overcome by our modern engineers. Again, the Kimball and the Lyon and Healy Buildings illustrate how the engineers are able to solve difficult problems without incurring prohibitive expenses. There the property is valuable, and therefore early returns on the money invested are highly desirable. But the owners had the utmost confidence in the architects and engineers and the buildings are now almost completed to the satisfaction of everybody concerned.

Systematic Shop Methods

At the American Bridge Company's plant the competence of engineers is again illustrated. In order to fabricate the structures economically they have devised an almost perfect system of handling the materials in their shops. The cranes deliver the plates and shapes to the multiple punches, and when the punching is done, the pieces are carried down the shop a few feet and fitted together. They are scarcely fitted up before they are rushed on to the next bay or shop, and the riveter practically finishes the job. It seems that the steel is hardly given a rest from the time it is drawn off the furnace until it is set in place in a railroad bridge, or in some tall building. Then it does not always get a real rest, for some of the buildings in Chicago that are comparatively new are being replaced by newer ones. The Boston Store Building is an illustration of this fact. The old building was scarcely seventeen years old before giant cranes pulled it apart to make room for a more modern structure. Here was surely a test of engineering ability. In one hundred and forty-two days the old building was demolished, the new one was erected, and business was resumed.

The Lake Traffic Problem in Chicago

One of Chicago's greatest problems is the handling of lake traffic. At last the engineers have been given a chance and the new Municipal Pier stands as a monument to their ability. Here thousands of piles, other thousands of cubic yards of concrete, and still other thousands of tons of steel have been assembled to form at once a beautiful and a useful pier. The engineer of today recognizes that aesthetics can not be disregarded in his public works. So great board walks and promenades have been provided on this pier that is primarily intended to relieve the congestion in the Chicago River. This is probably the largest undertaking of its kind.

THE RAILROAD PROBLEM

The lake traffic has not offered the only traffic difficulties in Chicago. The railroad problem probably should be given first place. On the South Side, at Seventy-ninth Street, two railroads crossed at street level. Trains passed so frequently that it was impossible for the street cars to keep up with any regular schedule. The engineers were called upon and they immediately set about relieving the difficulties by building a three-level crossing. All this was done without interfering with the enormous traffic. The street had to be depressed—necessitating rebuilding of sewers, relaying of sidewalks, pavements, and car tracks—one railroad had to be raised high enough above the street to afford clearance for the street traffic, and the other railroad had to be raised high enough to afford clearance for the railroad below. All this was achieved while hundreds of trains rushed by undelayed.

CROSSING THE CHICAGO RIVER

Traffic problems have called upon the engineers, again, to provide means of crossing the Chicago River. At Lake Street the most difficult problem arose. Here surface cars and elevated trains cross the rived at short intervals. The old swing bridge had to be replaced and a specially designed double-decked bascule bridge was erected while the old bridge remained in use. It is the expectation of the men in charge that in the change from the old to the new bridge traffic will be delayed only twenty-four hours. This is another example of the ability of engineers to handle difficult situations. On the North Side the demand for water is threatening to exceed the present supply. Accordingly, work on a twelve-foot tunnel designed to extend five miles out under the lake was begun about a year ago, and at present about half of this distance has been covered. Here, as everywhere else, systematic efforts accounted for the progress.

MODERN MACHINE EFFICIENCY

Probably the second striking fact that was brought out was this: enormous amounts of work were being done with a comparatively few men. At the steel mills at Gary men were notably conspicuous by their scarcity. Great masses of white-hot iron were rushed over the rolls and shaped into plates with only a half-dozen or so men in sight. At the American Bridge Company's plant great machines were doing the work of many men. Instead of having men mark each hole with a hammer and a center-punch, and then having another man and a machine

punch one hole at a time, great multiple punches were measuring off distances, marking and punching, all at once.

So it was everywhere. Wherever mechanical power could be used, men were displaced. On the newer buildings material was being hoisted rapidly by steam power; in the Wilson Avenue Tunnel the debris was being hauled out by a gasoline locomotive, at the new Field Museum steam power was used to raise the concrete to a point from which it would be distributed by gravity to any point desired; everywhere power was used to mix the concrete. So our modern engineering practice has led to the building of great machinery, and has been greatly helped by it.

If nothing more were to be gained in the form of detailed knowledge of the methods employed, the trip could be said to be worth while, considering the effect of the impressions mentioned above. We all came back with a more profound respect for the profession of which we hope to form a part in the near future, and with a clearer view of what will be expected of us as civil engineers.

THE LOS ANGELES AQUEDUCT

By E. I. LEANDER

University of Illinois, 1917

[All junior civil engineering students are required during the second semester to write (1) a biographical sketch of some prominent engineer, (2) a review of some engineering book, and (3) and account of some noted engineering work. This article is one of the latter, and is presented here because of the information which it contains and as an example of the papers prepared by junior student.]

Necessity or gain is the incentive for most great undertakings. In the case of the City of Los Angeles, necessity was the reason for the construction of the great aqueduct, but its money-making power indirectly made it possible. In 1905 Los Angeles had a population of 350,000, which was increasing at the rate of 40,000 per year. The citizens foresaw that in a few years they would be confronted by a shortage of water. The supply at that time was taken from the Los Angeles River, but this was becoming inadequate. One must take into consideration the fact that Los Angeles lies in a semi-arid region where little or no rain falls from April to the last of October. This of course increases the

demand for water as is witnessed by the daily consumption of 140 gallons per capita, whereas London uses only 28 gallons per capita.

Engineers who have visited the Los Angeles Aqueduct call it the boldest project ever undertaken by a municipality. This is readily understood when one considers that the 234 miles of the aqueduct runs through the Mojave Desert and around the end of the foot hills of the Coast Range.

PRELIMINARY PREPARATIONS

When the project was first proposed in 1905, a commission was appointed to examine all possible sources of supply. The best then discovered was the Owens River, 250 miles north of Los Angeles and lying to the east of the Sierra Nevada Mountains. The water in this river was fairly good, and there was little danger of it being later polluted by the influx of civilization as the ruggedness of the country was largely prohibitive of permanent settlement. When the Owens River was decided on as the source, the city officials, acting with secrecy to forestall land speculators, bought a reservoir site of 120 square miles in the Owens Valley. The people then voted a bond issue of $24,500,000, and in 1908 construction work was started.

THE PATH OF CONSTRUCTION

The length of the aqueduct from the intake in the Owens Valley to the Lower Fernando Reservoir is 234 miles. From this reservoir the water is carried through 24 miles of steel mains to the city pumping station. The intake on the Owens River is about 200 miles due north of Los Angeles. The city, through purchase and special acts of Congress, acquired 125,000 acres of land in this valley. A reservoir is proposed 50 miles north of the intake to control the flow of water in the river in times of excess rainfall. Another site 6 miles north of the intake was purchased for the same purpose.

Starting at the intake, the first 24 miles of the aqueduct is an unlined canal, 10 feet deep, 38 feet wide at the bottom, and 62 feet wide at the top. The excavating was done with electrically operated shovels. The intake to the canals consists of a diversion dam and a weir. At the head of the Alabama Hills the ground drops rapidly, and for 16 miles the aqueduct follows the sides of the hills with many detours. Both electric and steam shovels were used in the excavation of this section, but the electric shovels were found to be more economical. In this excavation deep side hill cuts were frequently made, the uphill

side sometimes being as much as 70 feet. From the Alabama Hills to the Haiwee Reservoir 37 miles of concrete lined canal were constructed. Difficulties in the proper setting of the concrete were encountered due to the extreme range of temperature in that section of the country. When all work to the Haiwee Reservoir was completed, the water was let into that much of the canal.

Because of the topography at Haiwee two dams were necessary. One of them, a 120-foot trench down to bed rock, was necessary to hold the water securely. Both of these dams were constructed of concrete. The Haiwee Reservoir alone when filled will supply the aqueduct with a continuous flow for 80 days. From the outlet of this reservoir a drop of 200 feet in two miles makes the Haiwee Power House site practicable. In the next division, the Rose Valley, 13 miles of concrete covered conduit were constructed. The trench was lined with concrete and a concrete slab was constructed on top. All the concrete was plastered smoothly to decrease the loss of flow due to friction.

A detailed description of the rest of the aqueduct is impracticable here as the form of construction varies frequently, due to ever changing topography. Where a cañon or valley was crossed, a steel syphon was erected. There are eleven miles of this form of construction on the aqueduct. The entire work was completed with only one failure, that of the Sand Cañon pressure tunnel, later replaced by a steel syphon.

There are 52 miles of tunnel on the aqueduct; the longest, the Elizabeth Tunnel, is 5 miles in length. This tunnel was bored from both ends and when completed the center lines varied only one and one-eighth inches. The levels checked to five-eighths of an inch.

There are altogether four reservoirs on the aqueduct. Of these, the Lower Fernando Reservoir is formed by one of the largest hydraulically filled dams in the world, being second only to the Gatun Dam in Panama.

Preparatory to Construction

The work of preparation outrivals the actual construction of the aqueduct. The Southern Pacific Railroad Company constructed a 142-mile standard-gauge railroad along the line of the aqueduct by which to haul the needed 20,000,000 tons of freight. Mountain wagon roads to an aggregate length of 315 miles were constructed. To supply the water necessary in construction, three water systems were installed, comprising four reservoirs

and 150 miles of mains. For telephone communication, 460 miles of wire were erected. The power for the operation of the shovels and for the light was supplied by three hydro-electric power houses.

A New Cement Mixture

The most radical departure from ordinary usage was the manufacture, by the city itself, of the cement necessary for construction. Clay and limestone deposits were purchased by the city, and a municipal cement mill was erected at a convenient point. Commercial cement was then selling for $2.25 a barrel; but the city found that it could manufacture a suitable supply at a cost of $1.30 a barrel. By mixing this with tufa, one-half to one-half, the cost was reduced to $0.86 per barrel. This mixture of tufa and cement was an innovation in the cement field. It was found to be harder than the pure Portland cement. It did not harden as quickly, but after the first seven days its strength surpassed that of Portland cement. The manufacture by the city of the cement was a material help in keeping the cost of the aqueduct well within the original estimate.

It is seldom that a project of considerable size is completed without a material increase in cost over the original estimate. The Los Angeles Aqueduct, however, attained this distinction. One reason for this was that politics and graft were an unknown factor in its construction. The city felt so great a responsibility in undertaking this huge project that the citizens were very careful to eliminate anything that savored of politics or party strife. The fact that the city did its own work, however, was the big factor in keeping the cost down to a minimum. Only one part of the construction was let by contract. This was nine miles of comparatively easy excavation in the Antelope Division. Using this as a basis, cost records were made for the whole aqueduct, and it was estimated that by letting the whole job by contract, the project would have cost the city of Los Angeles $40,000,000, whereas the cost of the municipal construction was $24,500,000. Although the cost of the aqueduct was kept down to a minimum, it would have been a good investment even with a much greater cost.

Results of Good Supervision

One other thing that helped keep the cost down to a minimum was efficiency. Hard work was stimulated by the installation of a bonus system. For every ten-day period the engineers estimated how much work should be done by each squad. For all

work over this the men were paid a bonus commensurate to the increase. Each squad was also kept informed as to how their work compared to the work of every other squad. In this manner intense rivalry was created, and consequently world's records in tunneling and excavating were repeatedly made and broken.

There was no reduction of the efficiency of the men due to liquor. When the aqueduct was first planned many saloons were built along the line. A law was soon passed, however, by the state legislature prohibiting the sale of liquor within four miles of the aqueduct camp.

Double Source of Revenue

The primary cause of the construction was of course to provide an adequate supply for the various needs of a fast growing city and for irrigation purposes in the outlying districts. This in itself was reason enough for the great undertaking. The city, however, intends to take advantage of the 1500 feet of fall, and by erecting hydro-electric plants at various places, will develop 120,000 horse power of electrical energy. The installation of these plants will bring the total expenditure up to $31,500,000. The revenue derived from the sale of the electric energy will be augmented by the sale of water for irrigation purposes. The surplus water will provide for the irrigation of 135,000 acres. The net income from the sale of water and power is estimated at $4,425,000 annually. This is a return of about 14% on the investment. The completion of the aqueduct helped to set property and land values on a firm basis. Dry land in that country is worth $20 to $50 per acre, while irrigated land is worth from $250 to $500 per acre. The assured water supply is thus of great economic value to that section of the country.

The success of this huge project is largely due to the personality of its designer and chief engineer, William Mulholland, and of his principal assistant, J. B. Lippincott. It is a job of which Los Angeles may well be proud, and the successful completion instills confidence and courage into the citizens of other municipalities which are in need of similar public improvements.

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EDITORIAL

In this issue, which is composed of articles from the Civil Engineering College, there are presented many things which should be of interest and value to every engineer whether he is a civil engineer or not. In some of the articles, the results of tests and investigations, both practical and theoretical, have been very clearly explained. In others, we are given an insight into some of the projects the civil engineers of today are undertaking.

C. E. SOCIETY NOTES

Mr. D. B. Ohrum, '17, gave a talk to the C. E. club on "Railway Organization and Maintenance of Way." The points of Mr. Ohrum's talk are well developed in his article in the last issue of the Technograph.

On Friday, April 7, Prof. W. M. Wilson gave a most interesting lecture on "Types of Movable Bridges." The lecture was illustrated by slides showing views and diagrams of the various types of movable bridges in use. Among these were views of pontoon swing bridges, center pivot swing bridges, double leaf swings, Bascule, Scherzer rolling lift, Strauss bascule and many other types. Prof. Wilson spoke of the principles of operation of all of the bridges and of the advantages and disadvantages of some of them.

M. E. SOCIETY NOTES

On March 23d the Mechanical Engineering Society heard Miss Harbarger of the rhetoric department talk on the subject, "Rhetoric and the Engineer".

Miss Harbarger commented on the increasing ability of engineering students in rhetoric, and even stated that an engineering section was the desirable section from the teacher's standpoint.

V. S. Day.

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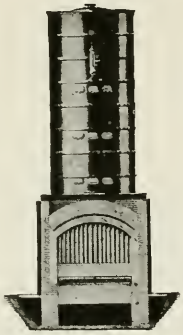

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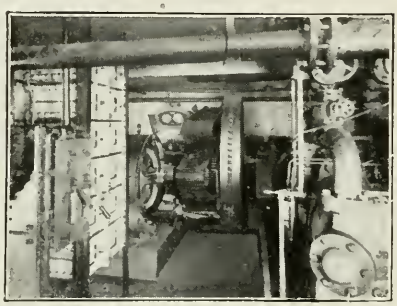

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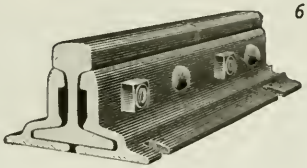

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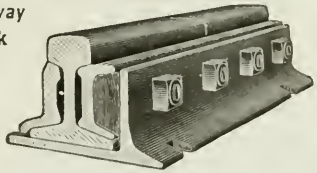

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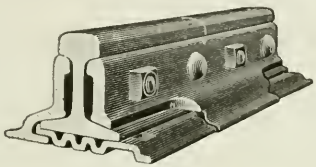

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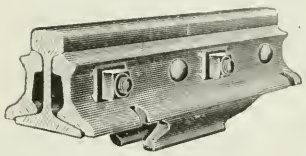

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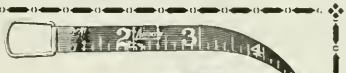

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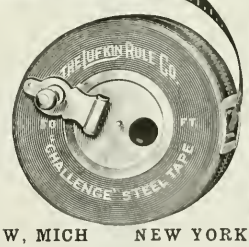

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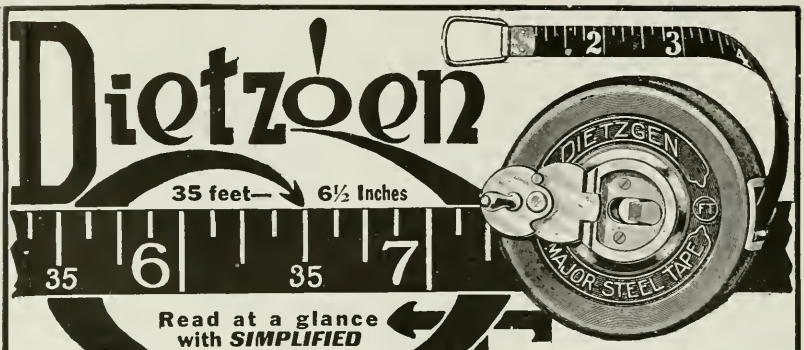

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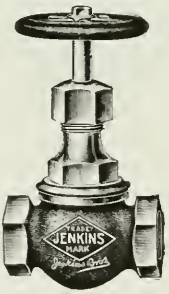

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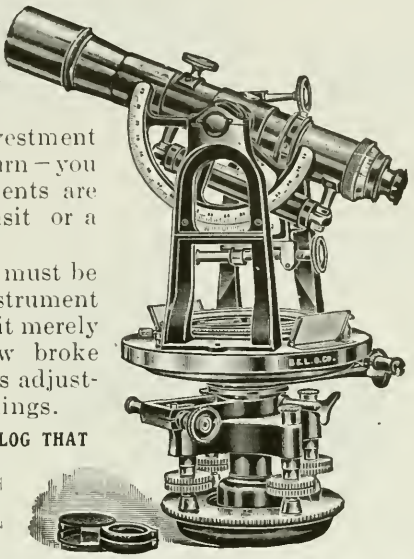

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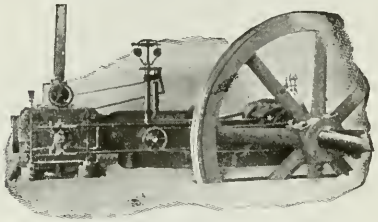

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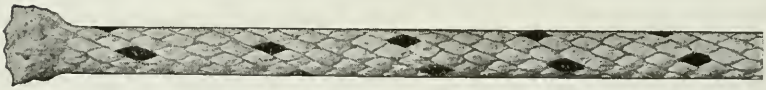

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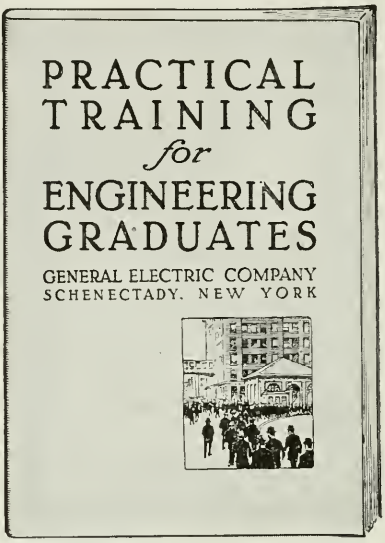

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